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Management Consulting & Research, Inc. (MCR) has developed an approach for analyzing the use of concurrent scheduling of program activities as a strategy for shortening the acquisition cycle. This approach, designed to be used by the Project Management Office (PMO), identifies activities suitable for concurrent scheduling and considers the risks associated with these decisions in terms of project cost and schedule targets. The methodology is composed of seven steps which are used to: initially structure the schedule and identify

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PREFACE

Management Consulting & Research, Inc. (MCR) has been tasked by the Office of Naval Research (ONR) under Contract N00014-81-C-0764, to develop techniques for shortening the weapon system acquisition cycle by the use of concurrency.

MCR has proposed a two-phase study for performing this analysis. The Phase I effort has concentrated on developing guidelines for the Program Manager (PM) to:

- identify and select program activities amenable to concurrent scheduling, and
- generate checklists that can be used in evaluating the cost and schedule risks associated with concurrency decisions.

This technical report documents MCR's Phase I efforts in the area of research on concurrency.

MCR would like to express our appreciation to the various technical groups and individuals who have provided assistance in this research.

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LIST OF EXHIBITS (Cont'd)

I. INTRODUCTION

MCR was tasked by the Office of Naval Research to develop techniques to enable Project Managers (PMs) for major acquisitions to:

- determine where it may be possible to shorten the acquisition cycle by the use of concurrency; and
- quantify the risk associated with such a schedule change.

MCR's objective for Phase I of the proposed two-phase study has been to develop guidelines to be used by the PM to:

- identify and select program activities amenable to concurrent scheduling; and
- generate checklists that can be used in evaluating the cost and schedule risks associated with concurrency decisions.

In addition to accomplishing these tasks, we have also made recommendations for the further development of planning tools required by PMs.

A. BACKGROUND

The first major weapon system procurement in the U.S. occurred on March 27, 1794 when Congress authorized the building of six large frigates by the U.S. War Department. Some seventeen months later, six keels were laid. Due to schedule slippage and cost overruns, the program was cut back to three frigates.1/ Now, almost two hundred years later, the problems of schedule slippage and cost overrun are being "rediscovered."

1/ Decision-Making for Defense, Charles J. Hitch, University of California Press, Los Angeles, CA, 1965.

The difference now is that the concept of "concurrency" is being suggested as a solution.

General Bernard Schriever is credited with coining the term "concurrency" in early 1958 while describing the Air Force Ballistic Missile (AFBM) program. A 1958 report 2/ described this program and the Navy's Polaris program as successful examples of the "concept of concurrency." Throughout the 1960s, several programs, including several which were cancelled, such as MBT-70, F-111B, CONDOR and CHEYENNE, allowed production efforts to begin prior to completion of full-scale development. However, enough problems had occurred that were allegedly due to concurrent scheduling that by the Spring of 1969, then Deputy Secretary of Defense David Packard promulgated the philosophy of "fly-before-buy." Several studies also echoed similar concerns and advocated producing only after the system development had been completed. 3/ The formal guidance came in the 1971 version of DoD Directive 5000.1 which noted that one should not propose ". . . unnecessary overlapping or concurrency." 4/

By 1977, however, the concept of concurrency was beginning to be reestablished. Dr. Richard DeLauer, then of TRW, Inc.

2/ "The United States Guided Missile Program," prepared by the Legislative Reference Service of the Library of Congress for the Senate Armed Services Committee, referenced in the Congressional Record, January 27, 1959.

3/ Examples are the RAND Report, "System Acquisition Strategies," by Robert Perry, in June 1971; and the Blue Ribbon Defense Panel Report of July 1970.

4/ DoDD 5000.1, "Acquisition of Major Defense Systems," 13 July 1971.

and currently Under Secretary of Defense for Research and Engineering, chaired a Defense Science Board (DSB) Summer Study to examine the problem of the lengthening acquisition cycle.5/ The report noted that it often takes 12-13 years to complete the acquisition cycle from Program Initiation through Deployment. In fact the average time to DSARC II grew from two years in 1950 to five years as of 1977 according to the report. An illustration of some of the growth in the acquisition cycle for ships can be seen in Exhibit I-1, which shows the drastic increase in just the contract design phase. Of more importance was the report's observation that programs are not cancelled for reasons of concurrency, but rather for reasons of a technical or political nature, or because of changes in requirements.

Two recent articles describe the advantages of concurrency.6/ In addition, DoD Instruction 5000.2 now notes that:

> . . . consideration (should be given) to minimizing acquisition cycle time by planned concurrency. This may include increasing funding, overlapping, combining or omitting the phases of the acquisition process, or overlapping or combining developmental T&E with operational T&E. The amount or degree of such concurrency should be based on the extent of the potential savings in acquisition time balanced against technical, cost and supportability risks and national urgency in each acquisition program.7/

In order to effectively use concurrency as an approach for shortening the acquisition cycle, the decision-maker must

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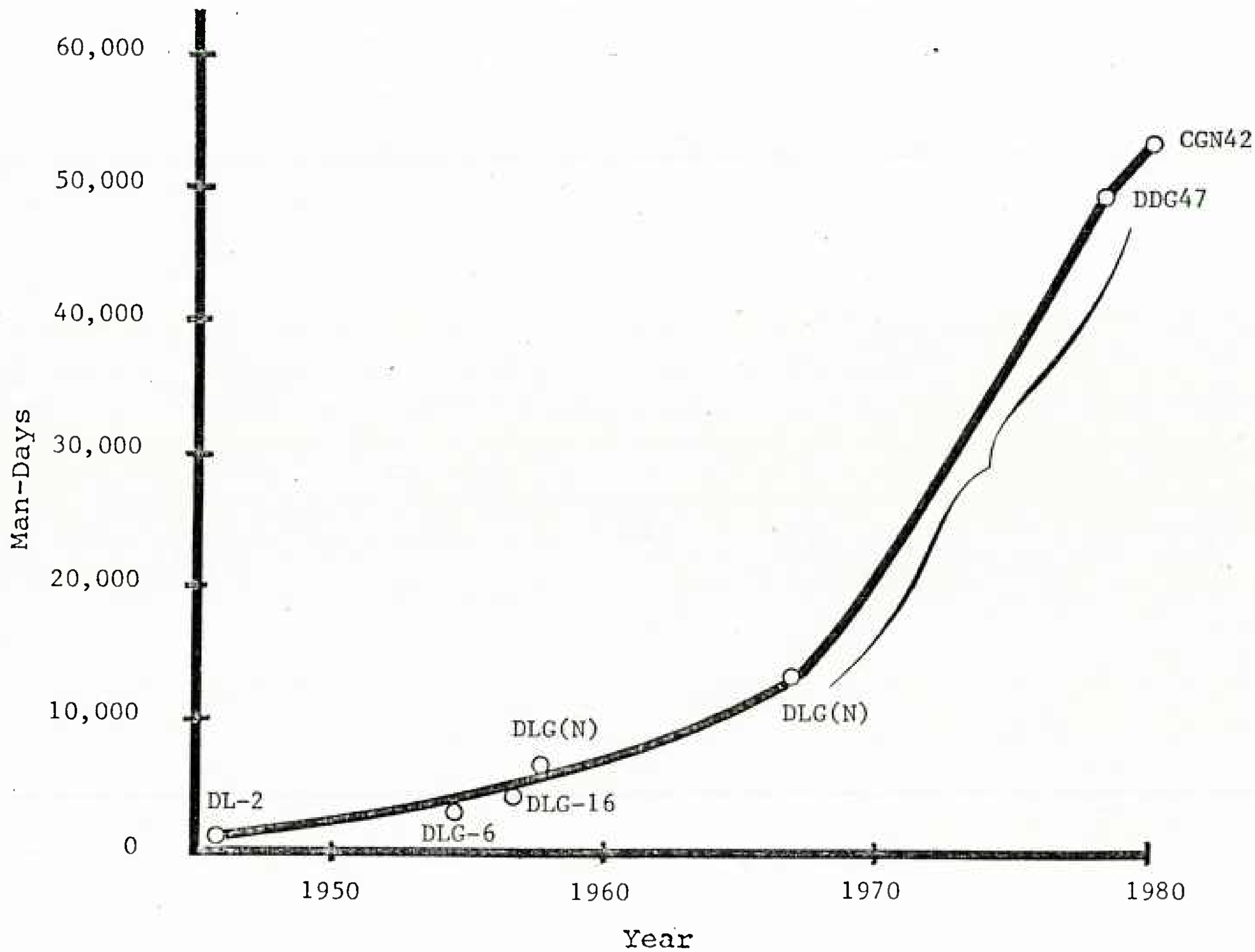
5/ "Acquisition Cycle Task Force Report," Defense Science Board Summer Study, 15 March, 1978.

6/ "Concurrency," Robert Gibson, Defense Systems Management Review, Autumn 1979; "Concurrency Today in Management," Thomas Harvey, Defense Systems Management Review, Winter 1980.

7/ DoDI 5000.2, "Major Systems Acquisition Procedures", 19 March 1980 (currently being revised, although this statement remains in the draft).



Source: "The Changing Nature of the US Navy Ship Design Process," Robert S. Johnson (1980). Course Material from the Navy Ship Design Process Course, The Catholic University of America.

Exhibit I-1. MAN-DAYS OF EFFORT TO PERFORM THE CONTRACT DESIGN OF VARIOUS DESTROYER TYPES OVER THE LAST 30 YEARS

be able to ascertain the potential impacts, particularly cost and schedule risks, of his decisions. There are currently no techniques available to the decision-maker which are specifically designed to be used in these analyses. However, in order to effectively use concurrency, such techniques are needed.

B. APPROACH

The current phase of this study was composed of three major analytical tasks:

- The first task involved background research into the extent of the availability of tools and techniques to assist the PM. In addition, attention was given to determining if previous or current research in the acquisition process had addressed the problem of concurrency. The background research was accomplished by way of:

  - a literature search,
  - a survey of acquisition analyses, and
  - an examination of high-level direction.

  A summary of this research is presented in Section II of this report;

- The second task in this study focused on developing a descriptive model to be used in making concurrency decisions; and

- The third task concentrated on elaborating on the descriptive model by developing methodologies to specifically analyze the risk of using concurrency to shorten the acquisition cycle. These methodologies were designed to:

  - consider the elements of risk at each phase of the acquisition cycle;
  - consider the concurrency alternatives available to the PM at each phase, and
  - determine the applicability of existing risk analysis techniques.

The discussion of the risk analysis tools and techniques is presented in Section III, while the description of the model and the supporting methodologies are provided in Section IV of this report.

II. SUMMARY OF BACKGROUND RESEARCH

The first step in this study was the identification of analyses that had already been performed in this acquisition research area. Also of interest were any directives which had been provided to decision makers on how to consider the question of concurrency, and if there were any existing tools or techniques useful in the analysis of concurrency. The basic approach taken in this research is described below.

A. APPROACH TO BACKGROUND RESEARCH

MCR's background research into concurrency focused on:

- directives, studies, and papers related to acquisition scheduling or planning which specifically address concurrency; and
- tools and techniques used, or which could be used, in acquisition scheduling.

This research was accomplished through the three-pronged approach of:

- a literature search focusing on:
  - acquisition scheduling, and
  - concurrency;
- an informal survey of organizations involved in acquisition research; and
- a review of government directives related to acquisition planning.

B. SUMMARY OF RESEARCH FINDINGS

The following are the most significant findings of MCR's background research. These findings have been arranged according to general topic.

1. Definition of Concurrency

There is no universally accepted or consistently used definition of concurrency within the context of weapon system acquisition program planning. There are, however, multiple interpretations of the term.

The 1977 DSB study[8/] restricted its definition of concurrency to:

> The conduct of the steps leading to production for inventory before the end of the full-scale development time span.

In examining the literature, however, one finds the most frequent interpretations of the term concurrency to include:

- parallel (back-up) technological development,
- simultaneous, but independent, subsystem development and testing,
- co-production, and
- overlap of dependent, normally sequential activities.

In addition, in examining alternatives to reduce the acquisition cycle time, it is clearly not sufficient to concentrate solely on the development/production overlap.

Concurrency should be examined in light of two alternative planning concepts:

- schedule protection - This concept recognizes that the need to extensively revise the program schedule may occur in the future. The PM can attempt to avoid a crisis later on by identifying concurrency options and scheduling alternatives before a crisis occurs.

8/ The Defense Science Board Summer Study, "Acquisition Cycle Task Force Report," 15 March 1978.

- schedule compression - Frequently, despite the best planning, a schedule must be revised due to conditions such as earlier schedule slippage resulting in less time available for the remaining activities, the moving earlier in time of a deadline, the avoidance of cost increases due to a longer acquisition cycle, etc. Any or all of these occurrences can result in the need to limit an already existing or imminent crisis.

2. Documentation Relating to Concurrency

There are few studies which have specifically addressed:

- the uses of concurrency,
- the specific effects of concurrency on program acquisition, or
- the application of concurrency in program scheduling.

Concurrency is used to varying degrees in virtually all programs, even if only as a means of providing on-going progress during decision and review periods. However, its use as a method of compensating for resource reductions and/or shortages has not been extensively documented. Because of this, it is difficult to determine where, and under what circumstances, the use of concurrency as such a tool has been successful.

In the past, concurrency has been considered the source, or a potential source, of substantial problems in the acquisition of various weapon systems. This has resulted in the tendency to avoid using concurrency, or in disguising and minimizing the use of it in acquisition planning.

The problem of effectively using concurrency is constrained by the general lack of training given to project

administrators and managers who plan and evaluate program schedules. MCR's investigation indicated that although tools are available for developing and analyzing certain aspects of schedules and networks, they have not been put in the context of a framework for analyzing the impacts of concurrency. The result is that PMs, or the groups in their staffs responsible for reviewing and adjusting the acquisition schedule, are forced to make decisions without being able to analyze the risks or impacts of their decisions.

In the past PMs have been forced to resort to concurrent scheduling in order to compensate for schedule delays. Frequently this has required the imposition of concurrency late in the project, when the precedence relationships among activities are most stringent, and the risk of failure is most costly.

3. Previously Suggested Alternatives to Reduce Acquisition Time

The following are some of the alternatives suggested by various sources:

- reduction of in-service review;
- reorganization of the DSARC process and reassignment of hierarchical responsibilities;
- explicit emphasis on developing techniques for shortening the acquisition cycle;
- increased emphasis on front-end analysis and development of design philosophies;
- committment to freezing designs, development of scheduled Top Level Requirements/Top Level Specifications (TLR/TLS), and the application of Pre-Planned Product Improvement (P^3I);

- increased coordination of the DSARC and PPBS processes, and

- development of techniques for quantitatively analyzing the impacts and risks of program schedule changes.

Many of these alternatives have been specifically addressed by the DoD Acquisition Improvement Program promulgated by Deputy Secretary of Defense Carlucci.[9/]

4. Pros and Cons of Concurrency

The basic arguments for and against the use of concurrency can be summarized as follows:

- Potential Advantages:
  - attainment of an earlier IOC,
  - increased likelihood of meeting intermediate goals and thresholds,
  - lower overhead costs,
  - work force continuity, and
  - increased worker motivation.

- Potential Disadvantages:
  - possible premature committment to high-cost program elements,
  - excessive and higher cost changes in design after production has commenced,
  - unreliable equipment in service, and
  - degradation of training because of multiple configurations and faulty systems.

The problem with any discussion of concurrency, however, is that of over-generalization. A given program can easily be affected by threat induced changes in IOC, overly

9/ In Memorandum: "Improving the Acquisition Process," Frank C. Carlucci, April 30, 1981.

ambitious schedules, redefinition of the need and changing technologies to meet that need resulting in program restructuring, as well as the need to compensate for program delays. One of the overriding conclusions of MCR's research, however, is that continuous risk analysis is required, as is careful planning of funding support and program stability. The Carlucci initiatives collectively solve many of the problems previously perceived as overriding disadvantages.

5. Official Directives and Guidance

Exhibit II-1 lists the major government directives considered to have the most significant influence on Navy PMs' use of concurrency in their programs. The memo of 31 March 1982 by Deputy Secretary of Defense Carlucci outlined 32 initiatives planned to improve the defense system acquisition process. Of these 32 initiatives, seven were interpreted as influencing the use of concurrency:

- Action 6 - Budget to Most Likely Cost,
- Action 9 - Improve System Support and Readiness,
- Action 11 - Budget Funds for Technological Risk,
- Action 12 - Front-End Funding for Test Hardware,
- Action 21 - Standard Operational and Support Systems,
- Action 30 - Give the Program Manager More Control of Support Resources, Funding and Execution, and
- Action 31 - Improve Reliability and Support for Shortened Acquisition Cycles.

AGENCY	DIRECTIVES AND REVIEWS
OMB	Circular A-109
OSD	DODD 5000.1 (Major System Acquisition) DODI 5000.2 (Major System Acquisition Procedures) DODI 5000.3 (Test and Evaluation) DODI 5000.39 (Acquisition & Management of ILS Support)
SECNAV	SECNAVINST 5000.1a (System Acquisition/Navy)
OPNAV	OPNAVINST 5000.42a (Weapon System Selection & Planning) OPNAVNOTE 5000 (Acquisition Documentation Reduction)
NAVMAT	NAVMAT P-9494 (Navy Program Manager's Guide)
NAVSEA	NAVSEAINST 9060.4 (Ship Acquisition Process) Ship Acquisition Reef Points Ship Acquisition Contracts Administration Manual
OTHER	DSMC Seminar on Impact of New Direction on the Acquisition Process

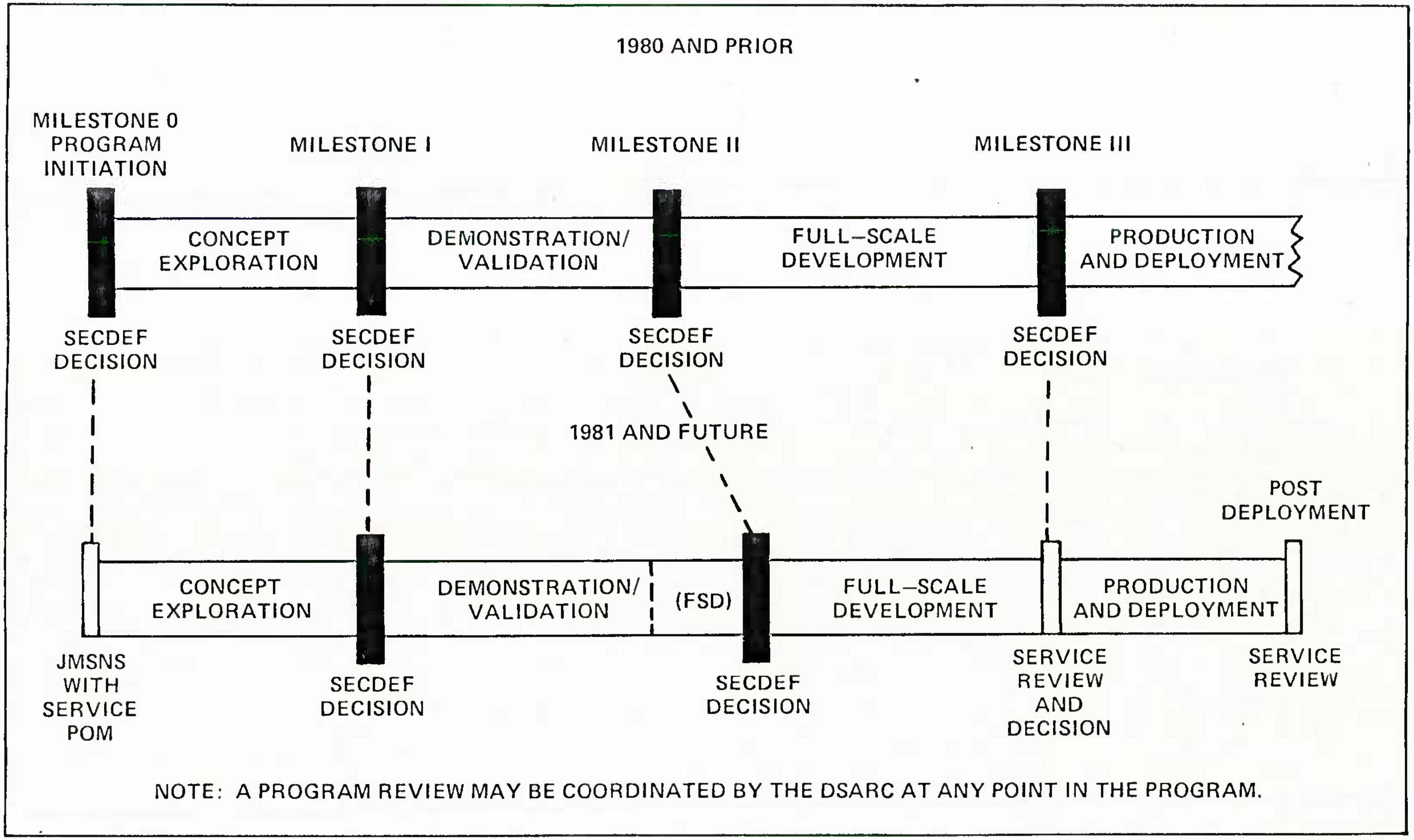
Exhibit II-1. SELECTED GOVERNMENT DIRECTIVES AND REVIEWS RELATING TO CONCURRENCY

Exhibit II-2 indicates the major changes in the DSARC review process, based on the current version of DoDD 5000.1, "Major Systems Acquisitions."

6. PM Concurrency-Related Needs

Based on MCR's research, several basic analytical needs were identified as required to be fulfilled in order for the PM to effectively use concurrency in a program schedule. He must be able to:

- define the amount or degree of concurrency deemed desireable for his particular program;
- determine the set of program activities which can be concurrently scheduled considering:
  - the amount of dependence on activities in the previous phase,
  - whether there are high costs associated with the particular activity,
  - whether failure to meet the schedule/cost objectives of the activity will produce long-term increases in the program costs, and
  - whether failure to meet the schedule/cost objectives of the activity will produce long-term increases in the program schedule;
- evaluate the cost-risk impact on program goals, thresholds and requirements; and
- justify these decisions to the Service hierarchy and OSD.



Source: "Manufacturing Management: Department of Defense Handbook for Program Managers," Defense Systems Management College, January 1982.

Exhibit II-2. MAJOR DEFENSE SYSTEMS ACQUISITION PROCESS

III. OVERVIEW OF RISK ANALYSIS TOOLS AND TECHNIQUES

In considering the use of concurrency as a scheduling option, it is important to be able to analyze the risks associated with each scheduling option. A body of knowledge already exists to allow analysis of some of the risks associated with concurrently scheduling program activities. However, in order to apply this body of knowledge, it is first necessary to identify and order the components of risk analysis and the tools and techniques applicable to analyzing schedule concurrency risks.

A. COMPONENTS OF RISK ANALYSIS

Typically, risk analysis is used to assess the degree to which a proposed system is likely to achieve its predicted performance within cost and schedule goals. In conducting a risk analysis it is essential to consider these three aspects:[10/]

- Risk Assessment - the identification of the degree of risk with respect to the realism, soundness, and credibility of the program's cost and schedule, and the system's performance.
- Risk Management - the development of a plan for managing all types of risk (risk minimization plan) as a function of time (i.e., Acquisition Milestones I, II, and III). Methods of minimizing risk, such as quality assurance, and other hedges against new technology failure are considered here.
- Risk Demonstration - the formulation of a test and evaluation demonstration plan will allow early identification of risks. Specifically, the steps required to reduce high risk program elements to acceptable levels as well as the cost of doing so are demonstrated.

10/ "Cost-Risk Procedures for Weapon System Risk Analysis," Gerald McNichols, Proceedings Annual Reliability & Maintainability Symposium, Institute of Electrical and Electronics Engineers, Inc., New York, January 1981.

A risk assessment includes not only an evaluation of the likelihood of success, but also must include assessment of the consequences of failure in measurable terms, usually dollars. Hence the concept of a "cost-risk analysis" becomes of interest. The analysis of concurrency, as part of the overall development of acquisition strategies, is part of the risk assessment process. It does not obviate the need for continued risk management or risk demonstration.

B. AVAILABLE ANALYTICAL TOOLS AND TECHNIQUES

Several models are currently available to assist in the analysis of acquisition schedules. These are typically network analysis or critical path techniques. Some of the best known include:

- Gantt Charting,
- Critical Path Method (CPM),
- Program Evaluation and Review Technique (PERT),
- Program Evaluation and Review Technique/Cost (PERT/-COST),
- Graphical Evaluation and Review Technique (GERT),
- Venture Evaluation and Review Technique (VERT),
- Simplified Network Analysis Portrayal for Planning and Control (SNAP), and
- Risk Information for Schedule and Cost Analysis (RISCA).

Many more techniques are currently in use.

The Services have not attempted to standardize or institutionalize one specific technique for Project Managers' use. Although there has been a move to advocate the use of the Total Risk

Assessing Cost Estimate (TRACE) methodology, or a similar method, by all Services, this model only considers cost uncertainty, not schedule uncertainty.

A basic tenet of the concurrency analysis methodology presented in this report is that there is no need to develop new techniques for analyzing project schedule networks and the risks associated with them. Rather, the need is for an analytical framework in which a PM can apply them. It is up to the PM to select the technique most compatible with the specific characteristics of his project.

Conceptually the cost/schedule risk problem can be illustrated by Exhibits III-1, III-2 and III-3. A baseline program schedule (presumably "optimal" in some sense) has a period of performance and level of funding associated with it. It also has implicitly (at a point in time) a chance of requiring additional time or cost. If a PM is willing to accept a non-zero chance of exceeding his funding level or time estimate, then he can begin to trade-off cost/schedule/risk. For example, suppose a 52-month program, funded at $52 million has a 10% chance of exceeding those values. Then the schedule can be shortened by additional funding, while maintaining that same 10% risk level. Alternatively, the funding level can be maintained or even reduced as the schedule is compressed simply by accepting an increased risk of exceeding those values. This is the risk assessment process. By using a proper risk management plan, however, the initially higher risk level can be monitored and minimized over time. Risk demonstration, through well designed

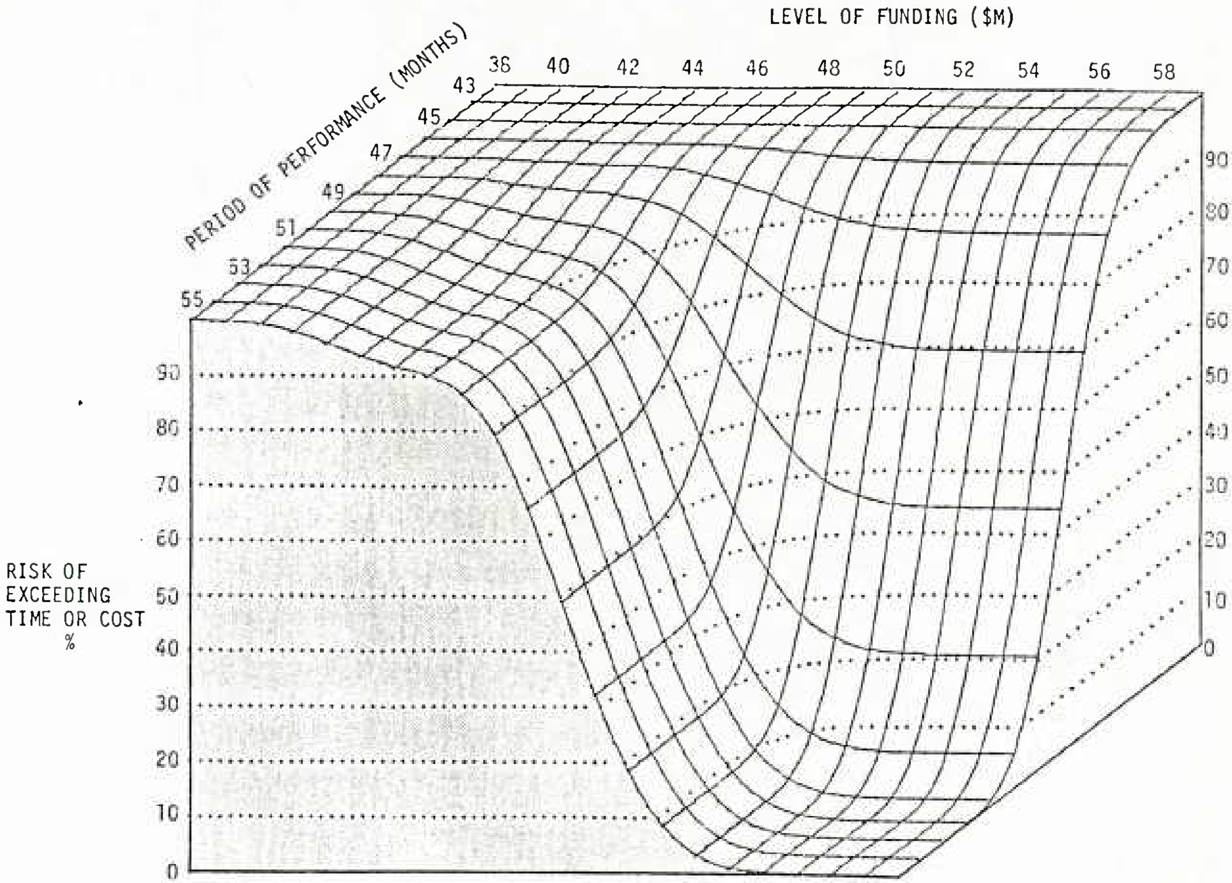


Exhibit III-1. JOINT COST/SCHEDULE RISK PROFILE

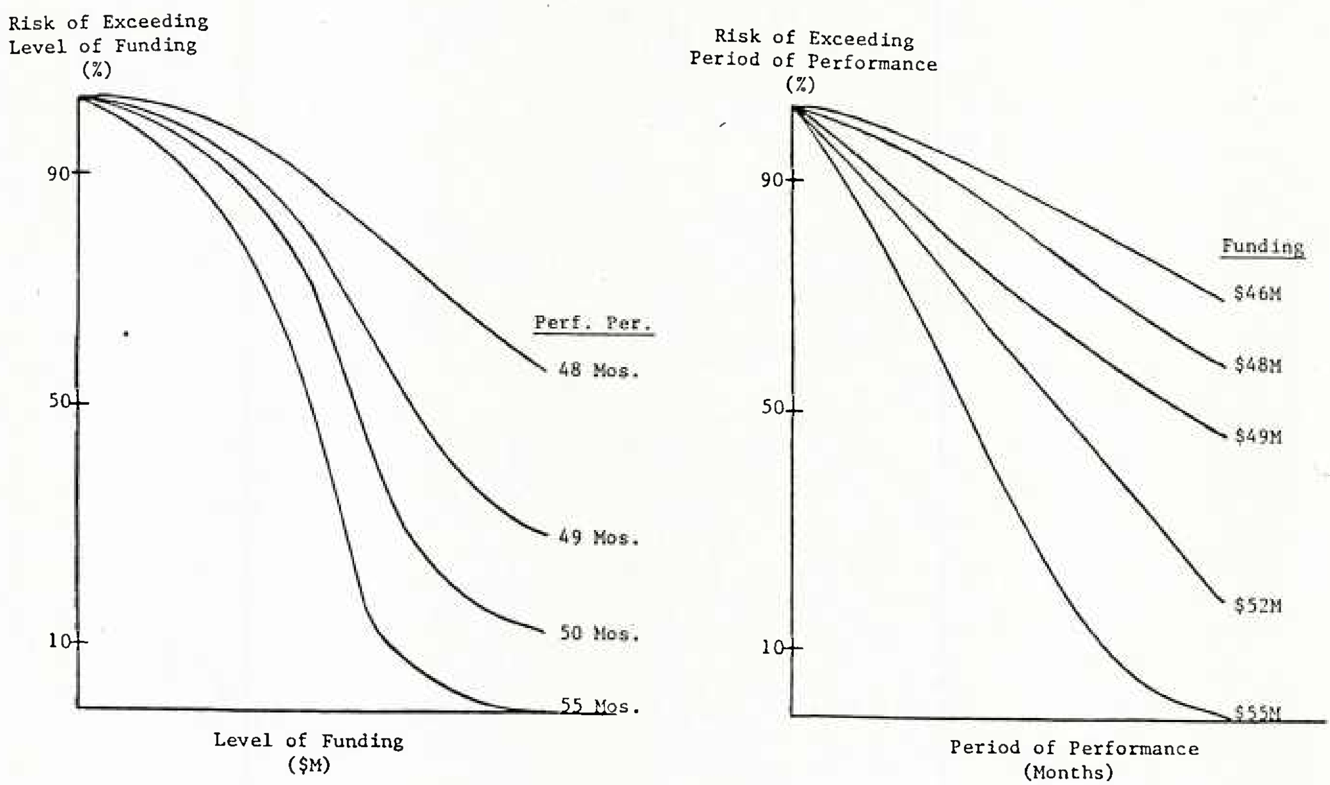


Exhibit III-2. COST AND SCHEDULE CONTOURS

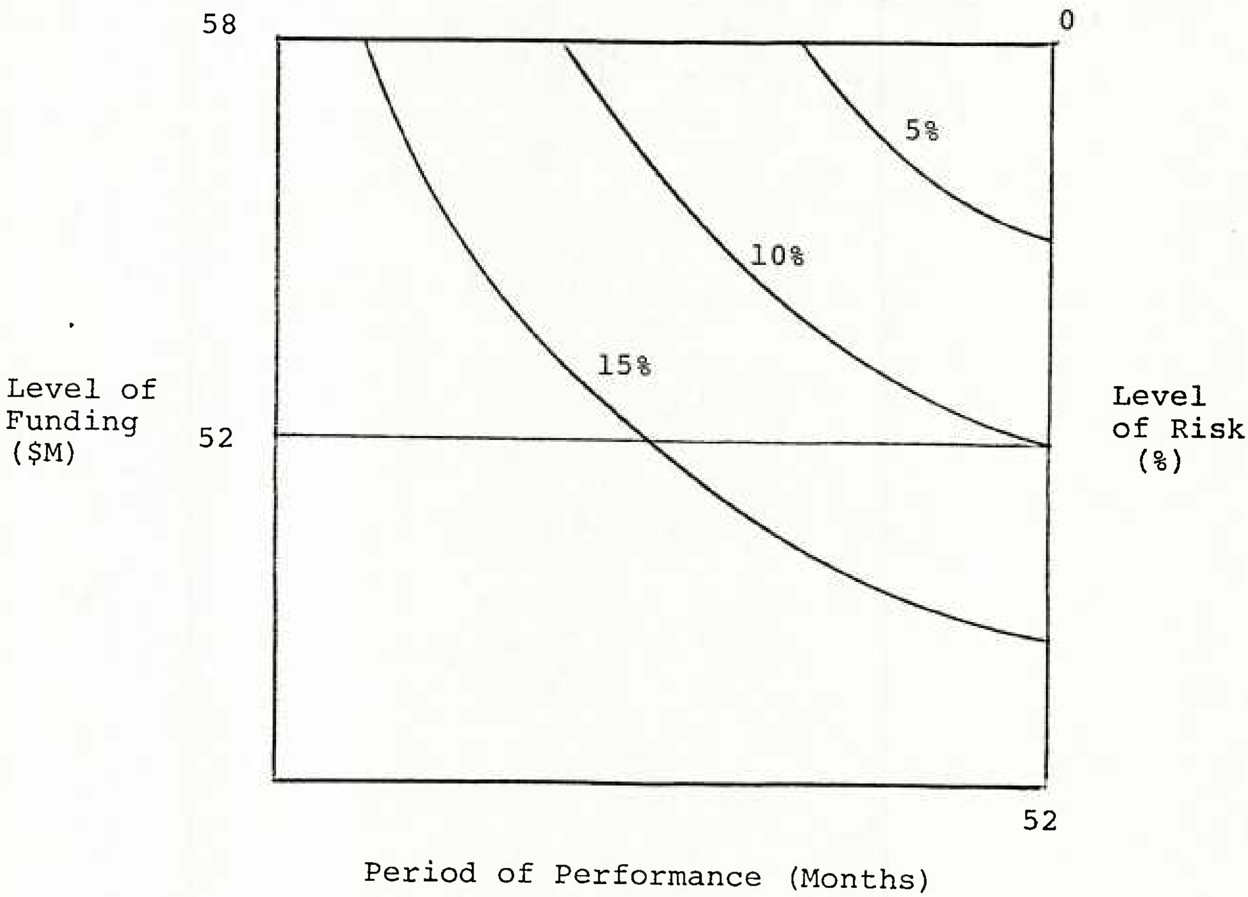


Exhibit III-3. RISK CONTOURS

test procedures, may result in a program lower in cost and shorter in duration than the inital "optimal" baseline schedule.

The concurrency analysis model incorporates these components of risk analysis. Initial risk "targets" are set as part of the development of the input information for generating the alternatives while the cost and schedule risks associated with the alternative schedules are assessed in the evaluation of the alternatives. On-going risk management is perceived as being an internal part of applying this methodology as part of the planning review process required in the project. Finally, the risk is demonstrated through the two-part process of generating and evaluating alternative schedules and monitoring the applicability of those alternatives through the project.

IV. DESCRIPTION OF MCR CONCURRENCY ANALYSIS MODEL

MCR's effort in this Phase I study was directed toward designing a model to assist the PM in making concurrency decisions. The initial step in this process was the definition of the scope of the model. The model must be sensitive to the characteristics of a schedule since its primary purpose is the review and revision of project schedules. The application of the model is left to the PM, as is the scope of the change or scope of the concurrency, which is dependent on such project-specific features as magnitude of the constraints, phase of the schedule, etc. These characteristics are specifically addressed in the model description below.

A. PROJECT SCHEDULE COMPONENTS

In attempting to understand what concurrency involves, specific factors and criteria must be developed for considering project activities and decisions required of the Project Manager. The basic components in creating project schedules must be identified. The project activities and events can be considered in light of these components.

Specifically, it is necessary to consider:

- Phases - acquisition phases such as Concept Exploration, Demonstration and Validation, Full Scale Development, and Production.
- Functions - major categories of work performed in, or under the direction of, the Project Management Office such as Technical Management, Logistics Management, Business Management, etc.,
- Task Areas - subtasks of functional work such as hardware design, software design, test and evaluation, etc. under Technical Management;

- Events - end points such as document delivery, design review meetings, milestones, and initiation of development of documents;

- Activities - efforts involved in preparing for a particular event, or following a starting event, such as preparation of a baseline and review of a procurement plan; and

- Organizations - groups responsible for performing activities such as the Project Management Office functional groups or contractors.

These must be presented in terms of time in order to produce a schedule.

In addition to these basic components, a project schedule is individualized based on two other considerations:

- System Type - generic type of weapon system related to the project schedule, e.g., ship, aircraft, missile.

- Subsystems - level three work breakdown structure elements of hardware, as defined by MIL-STD 881A, which may be on different developmental schedules, but which collectively constitute a viable weapon system.

Exhibit IV-1 illustrates representative acquisition activities for a notional ship acquisition project.

In examining the degree of desirable concurrency for a particular project many factors must be considered. The following considerations are briefly summarized here:

- factors influencing the applicability of concurrency,
- acquisition cycle-related problems,
- previously suggested alternatives,
- pros and cons of increased concurrency, and
- factors for changing project concurrency.

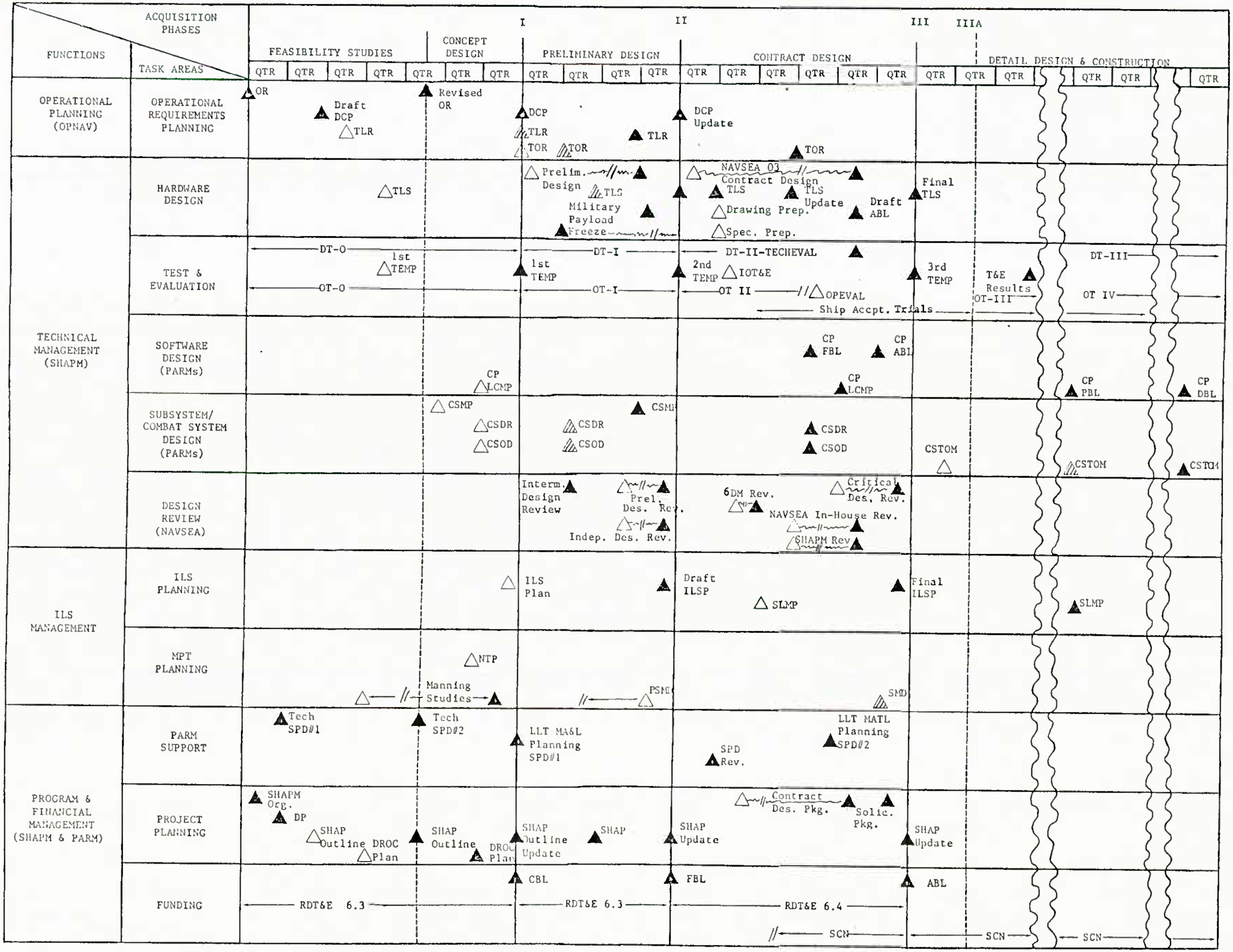


Exhibit IV-1. REPRESENTATIVE ACQUISITION ACTIVITIES

It is not clear that concurrency is applicable to all system acquisitions. Development factors such as design status, familiarity of technology, environmental characteristics, project personnel experience, and contractor availability/experience, and production factors such as production resource availability/manufacturing capability, and level of previous program involvement are all important. But so, too, is the discipline required (risk management) of scheduling far in advance of actual requirement (i.e., consider production and logistics problems very early in the cycle). Risks of technological advancement or lack of maturity of design balanced against high development cost or high cost uncertainty can doom a project and require higher costs of maintaining low-risk alternatives. There is a complex hierarchy of responsibility and review that also contributes to the problem rather than to the solution. In addition to these needs the program schedule must also be analyzed in terms of its sensitivity to external forces such as political and budgetary decisions.

B. OVERVIEW OF THE MODEL

The approach taken in developing a tool to assist the PM in making concurrency-related decisions has been to construct a logical framework for utilizing a progresive accumulation and refinement of data. The model itself is designed to be neither weapon system specific, nor sensitive to a particular level of detail. Rather, it is applicable to any system, with appropriate tailoring, and any level of organizational detail.

Exhibit IV-2 shows the structure of MCR's descriptive model. This model is composed of seven basic steps to be performed by, or under the direction of, the Project Manager. The first step involves the development of the initial project schedule which forms the basis for concurrency and cost/schedule risk analysis. It also includes the formulation of the rules and criteria for performing the analyses, and the identification of an initial set of concurrency options.

Having set up the problem, the second step concerns the considerations of the constraints that the PM must respond to in the schedule. These constraints may be pre-existing or newly imposed, endogenous or exogenous to the project. This step is closely related to the third step, determining the reason for considering concurrency. In evaluating the constraints the PM must determine the desirable scope of the concurrency, i.e., the phases, functions, task areas, and activities affected by the implementation of concurrency. In recognizing the motivation, the PM is also considering the ultimate purpose to be achieved by using concurrency as a scheduling mechanism, as well as the circumstances driving the decision, i.e., earlier schedule slippage, protection of the remaining schedule, incorporation of changing direction, etc.

In the fourth step, the PM determines the magnitude of acceptable risk to be considered in developing and selecting alternatives. This narrows down the set of possible alternative schedules which could fulfill the requirements. It is at this point that decisions are made about acceptable degrees of

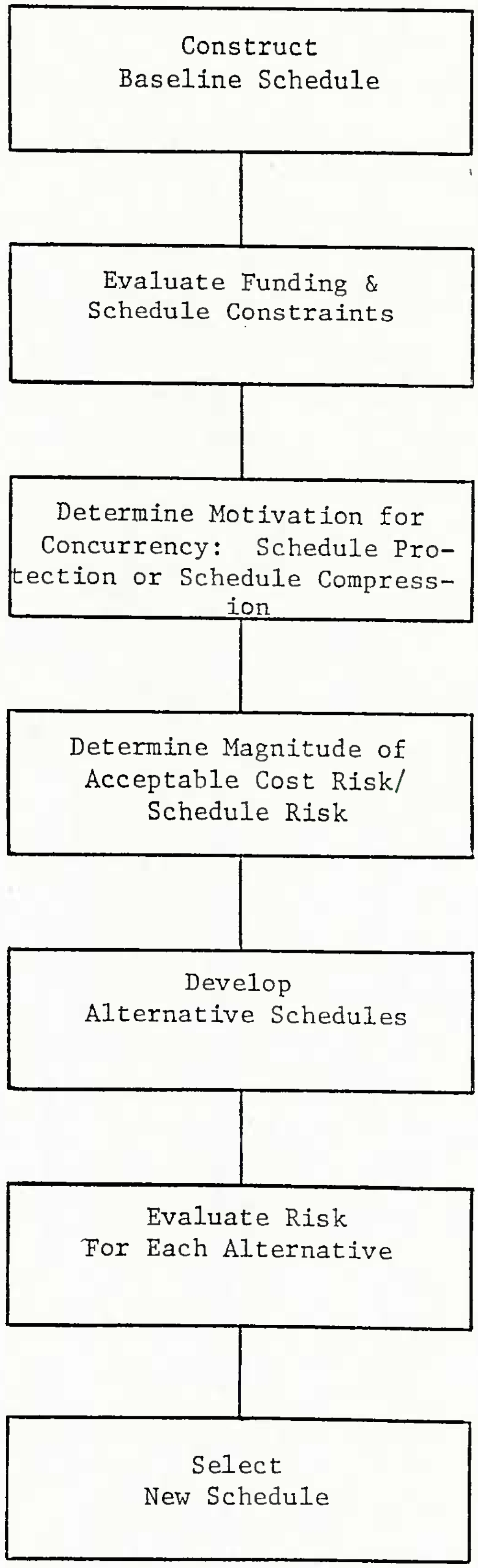


Exhibit IV-2. DESCRIPTIVE MODEL

concurrency and risk. Based on the analysis performed in the previous steps, it is possible that there may be more than one set of concurrent activities in an alternative, each of which will have to be decided upon.

The fifth step involves the development of alternative schedules which are within the scope of the preceeding constraints and risks. A variety of alternatives, addressing one or more of the previously selected sets of concurrency options, may be developed.

The companion to this step is the analysis of the risks associated with each alternative, performed in the sixth step. The evaluation of the alternatives is performed using checklists tailored to the particular characteristics of the system type, the stage in the development of the system, and the particular task areas and activities involved. Development of these structured checklists is begun with the selection of the concurrency options in step one and is continued through each step, incorporating the refined direction that is being developed in this process. They are tailored to respond to the PM's information needs necessary to make an actual decision.

Having evaluated and scored the alternative scheduling options, the final step is the selection of the alternative which most adequately satisfies the requirements at the time of the decision. Using the basic criteria developed in the first step, and refined for the actual decision, the PM trades-off the options presented in the alternatives among

cost, schedule, and risk in the program environment. The ultimate selection is the revised schedule. Although a single alternative may be selected in this process, it is often the case that other viable alternatives have been developed and should be monitored in the process of subsequent schedule reviews.

Initially, several assumptions are made:

- the Project Manager is assumed to have a Baseline Schedule;
- funding and schedule constraints can be defined;
- resource estimates (e.g., of time, cost and manpower levels) can be made for each schedule component;
- analysis of alternative schedules representing relatively fixed performance will be performed; and
- concurrency can be meaningfully considered in terms of potential savings in time versus cost risk.

The Top Level Hypotheses (TLH) are simply that:

- project schedules can be quantitatively and qualitatively evaluated;
- quantitative or qualitative risk analysis measures can be developed and applied to evaluate degrees of project concurrency; and
- the Project Manager can himself make meaningful decisions regarding shortening the project acquisition cycle using a structured checklist methodology.

Given the TLH, the PM must be able to intelligently apply available analytical techniques to his project in order to make concurrency decisions.

C. DESCRIPTION OF ANALYTICAL PROCESS

The following is a brief description of the analytical process represented by the steps listed in Exhibit IV-3.

Step 1. Construct Baseline Schedule
- 1.1 Develop Project Schedule Philosophy
- 1.2 Construct Baseline Networks
- 1.3 Identify Potential Concurrency Options
- 1.4 Develop Structure of Risk Evaluation Checklists

Step 2. Evaluate Funding and Schedule Constraints
- 2.1 Determine Significance of Constraints
- 2.2 Determine Scope of Concurrency
- 2.3 Relate Constraints to Concurrency Options

Step 3. Determine Motivation of Concurrency: Schedule Protection or Schedule Compression
- 3.1 Determine Extent of Internal Program Limitations
- 3.2 Refine Baseline Schedule Estimates
- 3.3 Reevaluate Preceeding Decisions
- 3.4 Develop Initial Set of Risk Evaluation Checklists

Step 4. Determine Degree of Acceptable Cost Risk/Schedule Risk
- 4.1 Develop Final Baseline Resource and Schedule Estimates
- 4.2 Determine Acceptable Degree of Concurrency
- 4.3 Determine Acceptable Degree Risk
- 4.4 Review Remaining Concurrency Options

Step 5. Develop Alternative Schedules
- 5.1 Select Constrained Concurrency Options to be Used in Developing Alternatives
- 5.2 Group Concurrency Options for Development of Alternatives
- 5.3 Generate Alternative Schedules
- 5.4 Determine Critical Path for Each Alternative

Step 6. Evaluate Risk for Each Alternative
- 6.1 Finalize Evaluation Checklists
- 6.2 Apply Checklists to Detailed Schedule and Subschedules
- 6.3 Score Each Alternative Based on Cost and Schedule Risk and Response to Constraints
- 6.4 Aggregate Data to Decision Making Level of Detail

Step 7. Select New Schedule
- 7.1 Review and Revise Decision-Making Criteria
- 7.2 Review and Revise Proposed Schedule-Monitoring Techniques
- 7.3 Analyze Results of Risk Analysis of Alternatives
- 7.4 Apply Decision-Making Criteria to Viable Alternatives
- 7.5 Select Alternative
- 7.6 Revise Existing Schedule

Exhibit IV-3. STEPS IN CONCURRENCY ANALYSIS MODEL

1. <u>Step 1: Construct Baseline Schedule</u>

Purpose: Construct foundation for making decisions on program schedules by performing initial analysis.

Approach:
1.1 Develop Project Schedule Philosophy (PSP)
1.2 Construct Baseline Network
1.3 Identify Potential Concurrency Options
1.4 Develop Structure of Risk Evaluation Checklists

The first step in addressing the problem of concurrency is to identify the specific characteristics of the project which must be identified in order to make decisions on adjustments to the schedule. Developing the project schedule philosophy involves construction of the policy and procedures or rules for organizing the analysis, and construction of the criteria for making scheduling adjustment decisions. It also includes determination of the level of specificity of the ongoing analysis, a reevaluation schedule for the project schedule throughout the acquisition, and a description of basic information requirements necessary for the analysis. This philosophy is subject to refinement, as is the schedule.

After developing the basic rules for considering the project schedule, the next substep is the actual identification of the activities and events to be scheduled, the development of projected values for each; the identification of the tasks and subtasks which compose each activity; and, finally, the arranging of this information in a set of networks, reflecting various levels of detail.

The third substep in constructing the schedule foundation is the identification of concurrency options. Not all

of the activities and events in a project schedule can be concurrently scheduled. Therefore, it is vital to identify for each schedule (the initial as well as subsequent revisions) those activities and events which <u>can not</u> be reordered or adjusted. Although initially identified when the program schedule is constructed, the concurrency options must be reevaluated as portions of the schedule are completed.

The final substep in the initial organization of the analysis is the development of the basic structure of the risk evaluation checklists. These checklists will be used in Step 6 to evaluate the alternatives.

2. <u>Step 2: Evaluate Funding and Schedule Constraints</u>

Purpose: To determine the potential scope of the concurrency requirements, based on specific funding and schedule constraints.

Approach:

2.1 Determine Significance of Constraints
2.2 Determine Scope of Concurrency
2.3 Relate Constraints to Concurrency Options

In this step the actual analysis of concurrency potentials is begun. The first step primarily concerns the development and organization of information in a manner useful to further analysis. This second step, evaluation of constraints, involves the further refinement of direction through a three-step process.

A basic assumption underlying this analytical process is that schedules should and need to be re-evaluated because they incorporate an approach which may no longer be appropriate.

Schedule inappropriateness may be due to a variety of reasons (more specifically considered in Step 3). However, it can be translated into constraints which reflect changes in resource requirements or demands. These constraints may be due to circumstances within the program or outside of it. They may take the form of restrictions on:

- the amount of time remaining to accomplish an activity in any of the schedule levels,
- the projected cost allowed to complete development,
- availability of organizations to perform the work, or
- the projected level of risk.

The characteristics of the constraints will, in turn, influence the potential scope of the concurrency. The scope relates to how extensive the concurrency may be, spanning phases, functions, task areas, activities or organizations. Less significant constraints may allow for restricting the scope of the concurrency to a few activities at the subschedule level. The more significant the constraints, in terms of total project resources, the more extensive the scope of the concurrency. The scope is tentatively determined in this substep and refined, if necessary, as the analysis progresses.

The final substep in Step 2 involves relating the constraints to the concurrency options (identified in the first step) within the tentative scope of the concurrency determined above. Many of the original concurrency options previously identified will be eliminated, since they are outside the scope of the projected concurrency requirements.

3. Step 3: Determine Motivation for Concurrency: Schedule Protection or Schedule Compression

Purpose: Determine the amount of flexibility and limitations existing within the project relating to alternatives open to the PM.

Approach:

3.1 Determine extent of internal project limitations
3.2 Refine schedule uncertainty and dependency estimates
3.3 Reevaluate previous decisions
3.4 Develop initial set of risk evaluation checklists.

This step is iteratively related to the preceeding step. In this step peculiar characteristics and conditions within the project are considered. Particular consideration is given to how they may influence or further constrain the potential options for developing alternative schedules. There are four substeps in this part of the analysis. The first three substeps are performed and, if necessary as a result of these analyses, the decisions made in Steps 1 and 2 are revised to take into account these additional constraints.

The first substep is directed toward identifying specific constraints which are known to exist within the project. Some of these constraints may prohibit rescheduling or reordering of activities and events which would otherwise be viable concurrency options. There are a variety of conditions which could produce this effect including already slipped schedules, previously completed activities, or activities already in progress which cannot be redirected or rescheduled. This

analysis will reveal the general orientation of the planning toward schedule protection or schedule compression.

In the second substep the preliminary estimates on the degree of uncertainty and the dependency of activities and events are reevaluated and refined, if necessary, to reflect the additional understanding of the program constraints. Related to this is the third substep in which previously made decisions on concurrency options and the checklist structure are reevaluated and modified, if necessary. Finally, an initial set of checklists is developed as a result of this analysis. These checklists are tailored to address the cost risk and schedule risk associated with the options used to generate the alternatives.

4. Step 4: Determine Degree of Acceptable Cost Risk/ Schedule Risk

Purpose: Finalize draft decision-making criteria and parameters for selecting alternate schedules.

Approach:

4.1 Develop final baseline resource and schedule estimates
4.2 Determine acceptable degree of concurrency
4.3 Determine acceptable degree of risk
4.4 Review remaining concurrency options

In this step the bases for developing the schedule alternatives are further refined and additional detail is developed. In the first substep the estimated resource requirements for accomplishing the remainder of the program schedule

are reviewed and final modifications are made. These estimates are for the cost, time and manloading required for each activity and event in the detailed schedule.

Based on these estimates, the degree of concurrency deemed to be acceptable is determined in the second substep. The degree of concurrency is based on the amount of overlap a dependent or successor activity has with its predecessor activities.[11/] The degree of concurrency acceptable to the PM will influence the amount of risk associated with a particular concurrency option. In determining the acceptable degree of concurrency the PM can decide an overall amount for the program, such as "no more than 10%", as well as acceptable amounts for each concurrency option, based on the perceived risks associated with each.

In addition to determining the acceptable degree of concurrency or amount of overlap among activities, it is also necessary to determine the limits of the risks the PM is willing to tolerate in shortening the acquisition cycle. Of particular interest are cost risk and schedule risk, and the relationship between the two. In this substep the PM makes a preliminary determination of the limits of risk and the circumstances under which additional risk will be undertaken.

11/ An operational definition of degree of concurrency is given and illustrated in Section V.

The last substep is the final review of the remaining concurrency options. Given the preceeding analysis, it is possible that some of the initial concurrency options may be eliminated or further constrained. It is important to determine that before proceeding further in the development of alternative schedules, since those constrained options form the basis for constructing the alternatives.

5. <u>Step 5: Develop Alternative Schedules</u>

Purpose: Translate sets of concurrency options into actual scheduling alternatives capable of being evaluated in terms of cost and schedule risk.

Approach:

5.1 Identify constrained concurrency options to be used in developing alternatives
5.2 Group combinations of options for each alternative
5.3 Generate Alternative Schedules
5.4 Determine Critical Path for each alternative.

In this step the actual alternative schedule or revisions to the baseline schedule are developed and prepared for further analysis. In order to do this the first substep involves determining which of the remaining concurrency options will be used as the basis for generating alternatives. It is conceivable that not all of the options will be applicable and an effort should be made to identify those that are not. The potentially large resources required to generate alternate schedules make that identification worthwhile.

Having identified which options will be used, the next substep involves arraying the options in alternative groupings.

It is possible to generate a variety of alternatives by varying the combination of concurrency options and the projected values and schedule for each. It is at this point that the PM has the greatest opportunity to be innovative, examining the specific needs of each option and determining the minimum requirements to begin each activity. These innovative approaches are considered in the context of the acceptable amount or degree of concurrency and risk, determined in Step 4.

Having developed the base for each alternative, the actual alternative schedules can now be generated. As part of this process it is worthwhile to review the preceeding analysis to insure that all of the internal and external constraints, as well as previously developed direction, are accounted for in the alternative schedules.

The final substep in this portion of the process is the determination of the critical path in each of the alternatives. It is possible at this point that some of the alternatives could be eliminated from further consideration due to the construction of the critical path.

6. Step 6: Evaluate Risk for Each Alternative

Purpose: Analyze alternative schedules as approaches for responding to constraints.

Approach:

6.1 Finalize risk evaluation checklists
6.2 Apply checklists to detailed schedules
6.3 Score each alternative based on cost and schedule risk, and response to constraints
6.4 Aggregate data to decision-making level of detail.

In this step the alternative schedules generated in Step 5 are evaluated to determine their appropriateness as approaches to dealing with the new constraints. The major mechanism for doing this is a set of evaluation checklists, tailored to particular phases, functions, task areas and activities of interest in the particular analysis. The first substep in this evaluation is finalizing the checklists initially developed in Step 3. The final version of the checklists should be tailored to address the particular activities and events which have been manipulated in the alternative schedule. They must be designed to produce a risk value, e.g., High, Moderate, Low, for each consideration. Since the schedules are generated at multiple levels of detail, the checklists must address those same levels. The checklists are now reviewed to ensure their consistency with the decision-making criteria originally developed in the PSP (Step 1).

After finalizing the evaluation checklists, they will be used to review each concurrency alternative. These checklists will be structured to address the activities and events rescheduled in the alternatives. However, in applying them, the values and degree of concurrency and risk determined for each option or group of activities must also be considered.

In the third substep the projected cost and schedule risks associated with each alternative are quantified. The result of this analysis is a ranking according to cost and schedule risk of the alternative schedules. This ranking reflects

the results of applying the checklists to each alternative, in light of the following considerations:

- degree of concurrency,
- total risk calculated and the peak risk estimated,
- amount of uncertainty associated with the resource and schedule estimates,
- dependency relationship among activities and events,
- overall influence of activity in program schedule and cost,
- stage of system technology development, and
- perceived scope of impact of decision/consequences of failure of schedule or cost projections.

Specific attention must be given to determining the risks of exceeding the:

- total costs if the concurrently scheduled activity fails to succeed,
- total schedule if the concurrently scheduled activity fails to succeed, and
- projected activity cost or schedule estimate.

The final substep in the risk evaluation portion of the analysis involves aggregating the risk values to the predetermined decision-making level of detail. Depending on the circumstances this may occur at the Summary, Detailed or Subschedule level.

7. <u>Step 7: Select New Schedule</u>

Purpose: To make decisions on schedule revisions based on analyzing risks associated with the alternatives.

Approach:

7.1 Review and revise decision-making criteria in PSP
7.2 Review and revise techniques for monitoring revised schedule and potential alternatives
7.3 Analyze results of risk analysis of alternatives
7.4 Apply decision-making criteria to viable alternatives
7.5 Select alternative
7.6 Revise existing schedule.

The final step in this analysis involves making decisions on the alternative schedules. In the preceeding steps preliminary decisions would have been made on how to decide which of the alternatives will be selected and how to evaluate the effectiveness of the revised schedule. The first substep in this final part of the analysis is to review and revise, if necessary, the decision criteria contained in the PSP. In the process of identifying and reviewing the concurrency options, and developing and evaluating the alternative schedules, it is quite possible that additional imperatives contributing to the decision-making process will be identified. The criteria should be modified to incorporate those additional considerations.

In addition to reviewing the decision-making criteria it is, at this point, also useful to review the originally proposed techniques for monitoring the revised schedule and the potential alternatives. In the set of alternative schedules some will be eliminated for future consideration simply by the choice of a particular alternative. However, some alternatives may not be totally eliminated as possibilities since their divergence from the revised schedule occurs later

in the project. These alternatives should be monitored as the schedule progresses to allow their maintenance as scheduling options.

The third substep involves analysis of the results of the risk analyses, performed in Step 6. The risk values developed for each alternative are arrayed on a graph illustrating their comparative cost and schedule risk values. Additional illustrations such as cost and schedule contours are also developed as part of this substep.

The fourth substep involves evaluating each of the risk-assessed alternatives in terms of the decision-making criteria. If constructed adequately, these criteria represent the significant points of concern and priorities of the PM. Each alternative is given a ranking based on the risk assessment and application of the decision-making criteria.

The fifth substep is the actual selection of the alternative or revised schedule, and the secondary alternatives which will be monitored.

The final substep in this process is the initiation of the revised schedule and incorporation of it into the project plan.

V. DISCUSSION OF POTENTIAL APPLICATIONS

The MCR concurrency analysis methodology has been designed for analyzing a wide range of constraints. It is not inherently limited to analyzing major, "program-shaking" decreases in acquisition-cycle time or cost. In addition, the methodology has not been tailored to a particular type of system but rather is flexible enough to be used with any program which has a schedule. It has been designed to gradually reduce the variety of alternatives the PM must consider through a multi-step process of refining scheduling requirements, constraints and decision-making criteria. This allows the consideration of only those alternative schedules which are not only feasible but practical as well. Finally, the alternatives are evaluated using methods tailored to the particular characteristics of the project.

In the previous section the basic MCR methodology and the rationale behind it were described. In this section the actual circumstances in which the PM must apply the methodology are discussed.

A. PLANNING NEEDS AND CONSIDERATIONS

One of the findings of MCR's research is that PMs have certain concurrency-related needs which must be recognized and responded to. These needs are the ability to:

- define the amount or degree or concurrency deemed desirable for a project;

- determine the activities which can be (or are amenable to being) concurrently scheduled;
- evaluate the cost-risk impact on the project goals, thresholds and requirements of concurrently scheduling activities; and
- justify these decisions to the Navy hierarchy and OSD.

In order to fulfill these needs the PM must work within the peculiar conditions of the project. There are several kinds of considerations with which the PM must deal; the major ones are:

- the organization of the Project Management Office (PMO)
- the activities and events which must be scheduled, and
- the allocation or distribution of this work among:
  - functional analytical groups within the Navy,
  - contractors, and
  - the PMO itself.

Each project can be organized differently, distributing the various tasks which must be accomplished among groups as determined by the PM and the particular characteristics of the project. However, certain basic functions must be performed simply due to the nature of a design effort, while others are dictated by the nature of the system being acquired.

Initial emphasis has been placed on the ship acquisition process. Although the methods used by the Navy to design and acquire major surface ships have undergone periodic revision, there is a fairly standard practice in general use at any point

in time. The current practice, specifically the PMS/SHAPM (project manager, ships acquisition project manager) organization and the activities and events generally identified with the TLR/TLS (top level requirements/top level specifications) design process will be used as the basis for this discussion of planning considerations. This does not mean, however, that all ship acquisition projects will be organized in this manner or that all projects will require this same set of activities and events. Rather, they are used here as specific examples.

1. <u>Organization of the Project Management Office</u>

Project Management Offices (PMOs) are generally designed to provide a core of analytical, technical and administrative personnel responsible for the accomplishment of the activities required to design and acquire a particular system. The actual size and composition of the project office is determined by, among other things:

- the particular system, or for our purposes, the particular ship project,
- the schedule and cost constraints and performance requirements of the project, and
- the management orientation of the SHAPM and his staff.

As generally organized now there are several different groups within the Navy which can be involved in the design and development of a Navy surface ship. Some of these organizations respond to the direction of the project manager, or SHAPM, while

others are responded to by, or provide direction to, the SHAPM. Exhibit V-1 shows the general relationship of the PM/SHAPM to these various groups. In project schedule planning, emphasis is placed on the activities to be performed under the direction of the SHAPM.

In the designing of ships, the PM, or SHAPM, must work closely with the Ship Design Manager (SDM) who is responsible for overseeing the technical design of the ship. This involves the integration of the ship hull, mechanical and electrical (HM&E) systems, with the Combat System Design and the Support System Design. Exhibits V-2, V-3, V-4 and V-5 show the basic relationships among these groups and the basic organization of the SHAPM, ship design team and combat system engineering team, respectively. The actual responsibilities of these groups will vary depending on the project and the development phase. In addition to these groups there are, within the Navy Systems Commands various functional groups specializing in providing particular types of project support, e.g., logistics analysis and contract support. While providing support to the specific project office (as well as several others), these groups may not be under the direct control of the SHAPM.

Part of the Project Manager's requirement in planning and reviewing the project schedule must involve the interrelationships among these groups and the activities they are performing on the project.

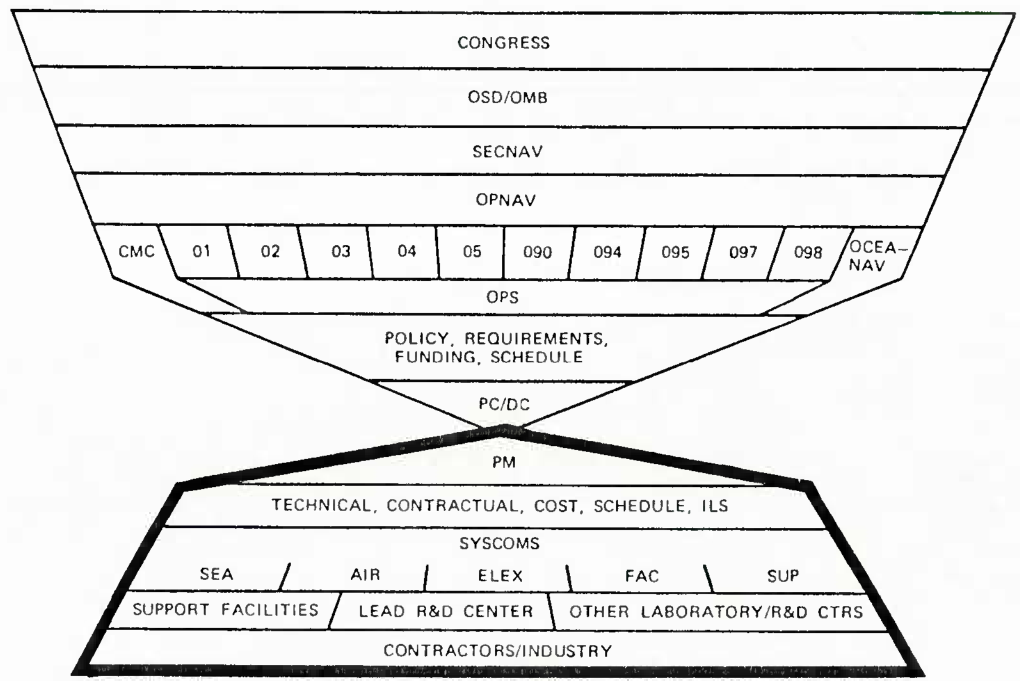


Exhibit V-1. ORGANIZATIONS RESPONDING TO PM DIRECTION

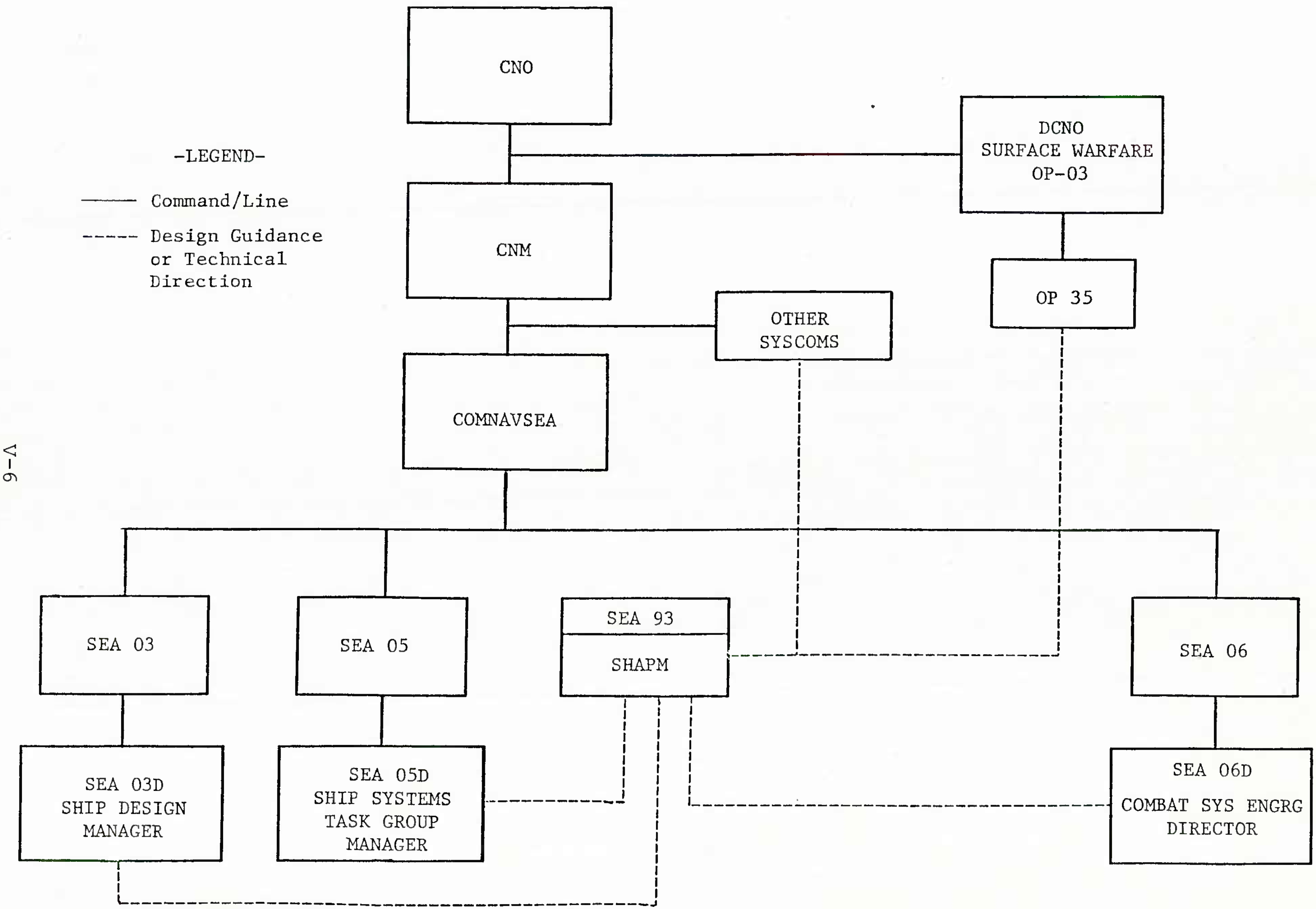


Exhibit V-2. PROGRAM MANAGEMENT ORGANIZATION

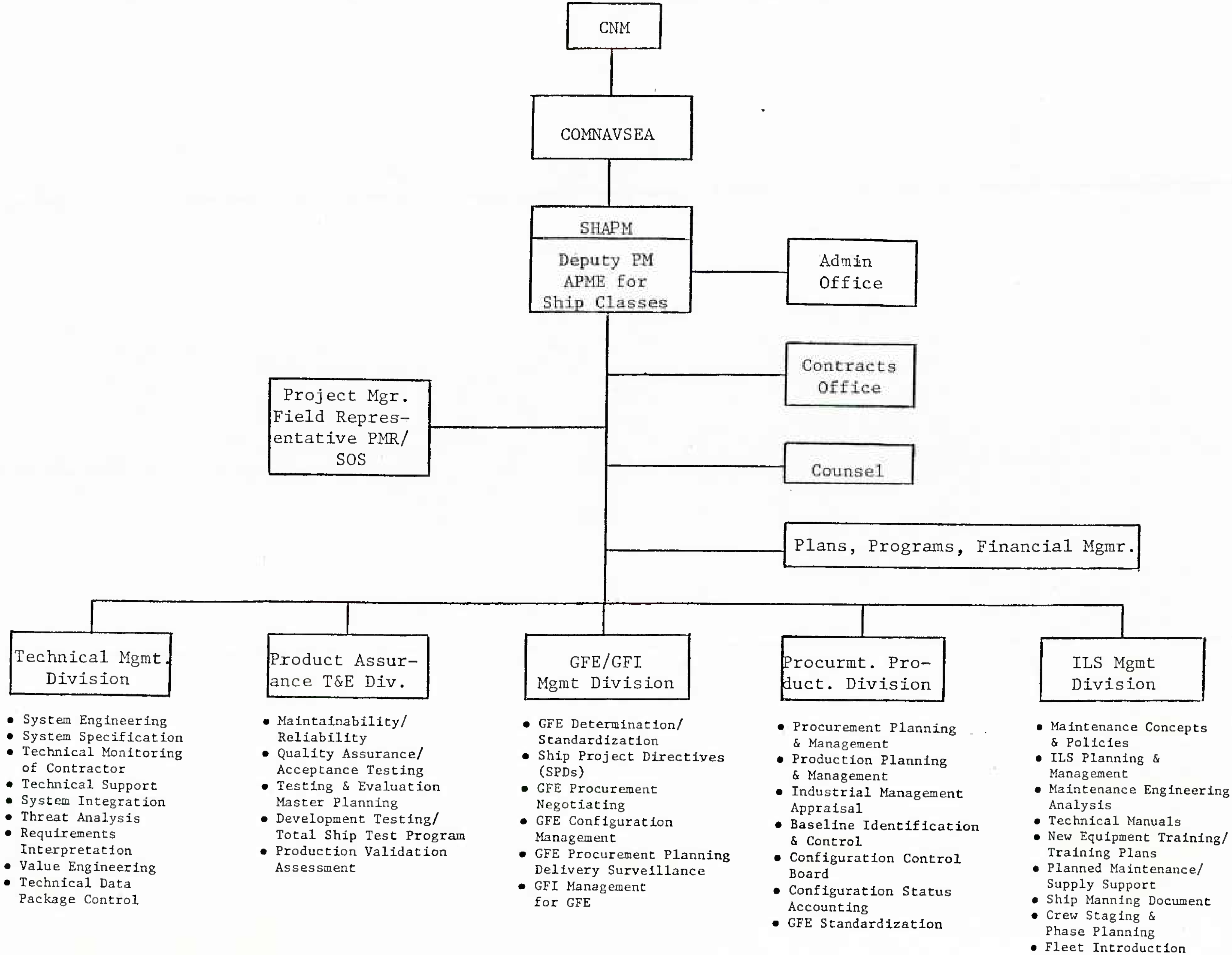


Exhibit V-3. TYPICAL SHAPM ORGANIZATION

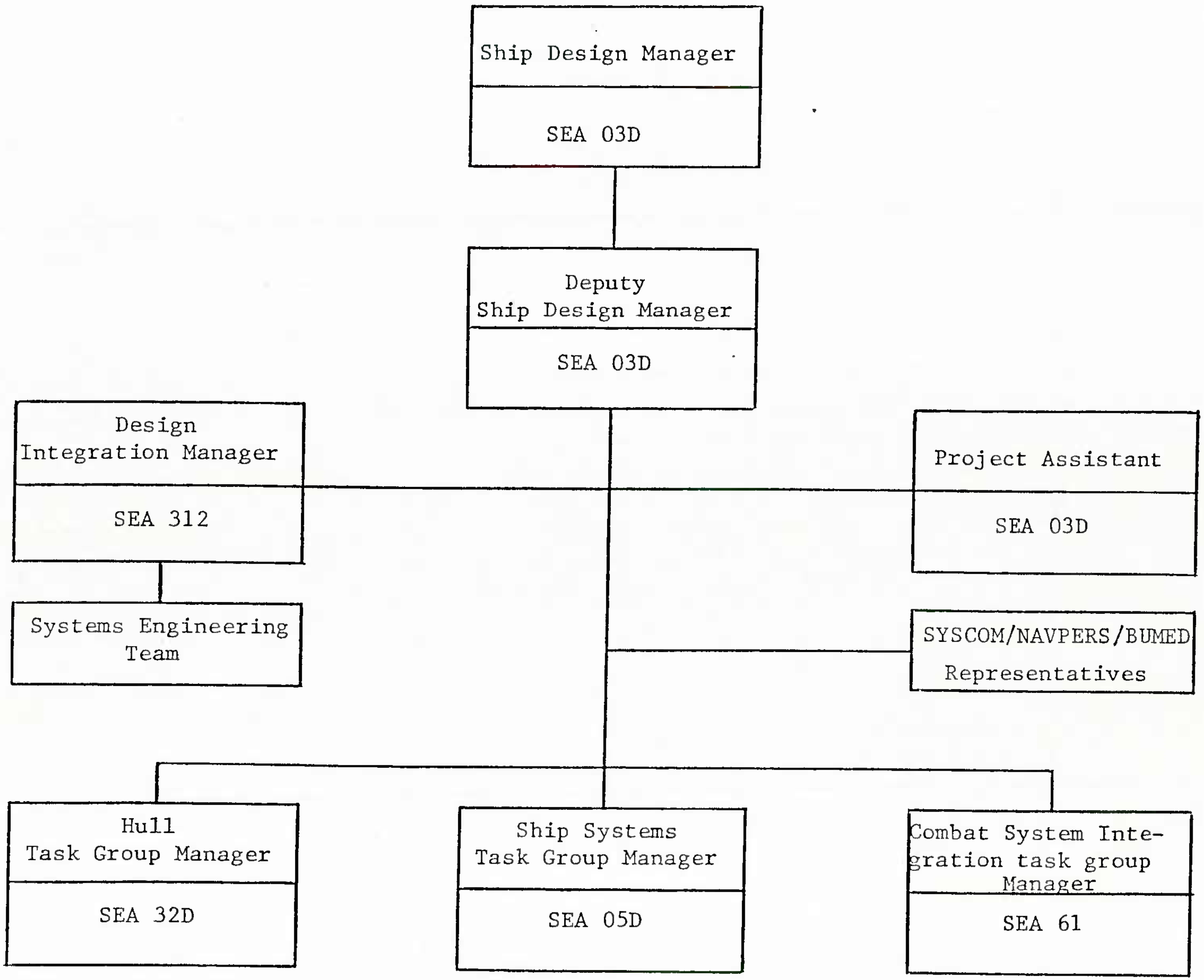


Exhibit V-4. SHIP DESIGN ORGANIZATION

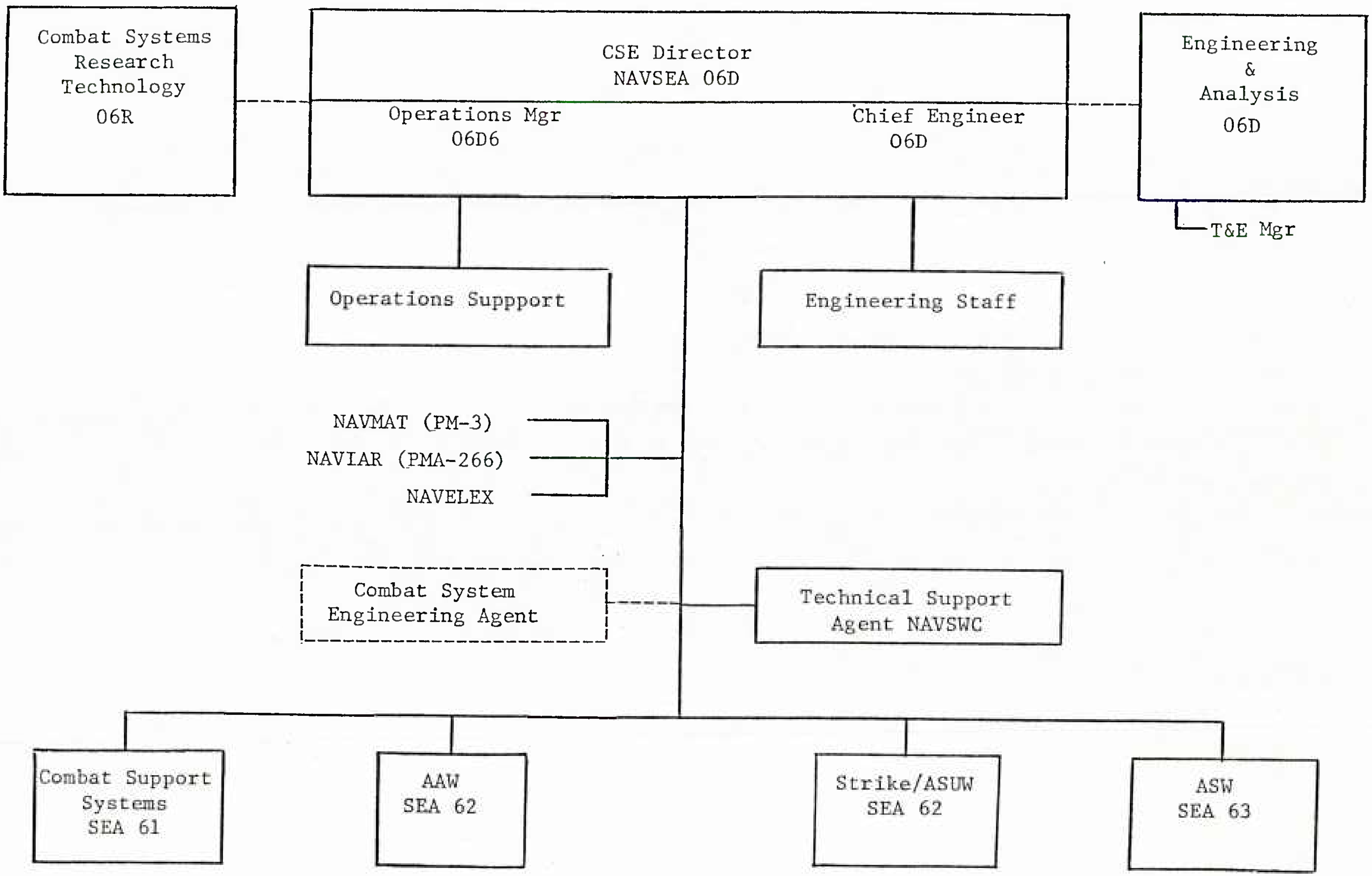


Exhibit V-5. COMBAT SYSTEM ENGINEERING ORGANIZATION

2. <u>Project Activities and Events to be Scheduled</u>

The design and acquisition of a ship system is accomplished through a sequence of activities and events. The activities and events are planned to be performed in an orderly fashion, moving through a logical progression culminating initially in the construction and testing of a lead ship, and ultimately in the completion of all of the ships of the class. Project schedules are the means by which these activities and events are planned and progress is monitored. The basic components of the project schedule, identified in Section IV, are (in terms of ship acquisition projects):

- Phases - design and acquisition phases such as Feasibility Studies, Preliminary Design, and Detail Design;
- Functions - major categories of work performed by, or under the direction of the SHAPM, such as Technical Management, Financial Management, and Integrated Logistics Support (ILS) Management;
- Task Areas - subtasks of functional work such as hardware design, software design, test and evaluation, etc., under Technical Management;
- Events - points beginning or ending an activity such as issuance of a ship acquisition plan (SHAP) outline; fixed decision points such as DSARC milestones, or prescribed document reviews and updates, such as SHAP and Decision Concept Paper (DCP) updates;
- Activities - efforts involved in preparing for a particular event, such as reviewing the SHAP, or in response to an initiating event, such as development of the preliminary TLR initiates preliminary design efforts; and

- Organizations - groups responsible for performing the activities, such as the SHAPM, NAVSEA 32D, NAVSEA 61, etc.

Schedules are developed for each group having responsibilities in the ship design and acquisition process. For this analysis three layers of scheduling detail have been identified:

- Summary schedules, displaying the major events in the project for each function and task area. Exhibit V-6 is an example of the summary schedule level of detail.

- Detailed schedules, showing an exploded view of task area, with additional detail on the specific activities occurring during the period of time, with indications of inputs from and outputs to other task areas.

- Sub-schedules, showing a still lower level of detail, giving an exploded view of each activity within each task area, with dependency relationships indicated.

These schedules form an interlocking hierarchy of detail and form the basis for developing the networks on which the concurrency analysis is based. As mentioned previously, these schedules and their related networks are developed for the activities being performed by the various groups involved in the ship design and acquisition process. Exhibits V-7, V-8, and V-9 illustrate examples of the design work breakdown structures related to the development of surface combatants. Schedules would be developed for the activities required for and related to each of the elements in these structures.

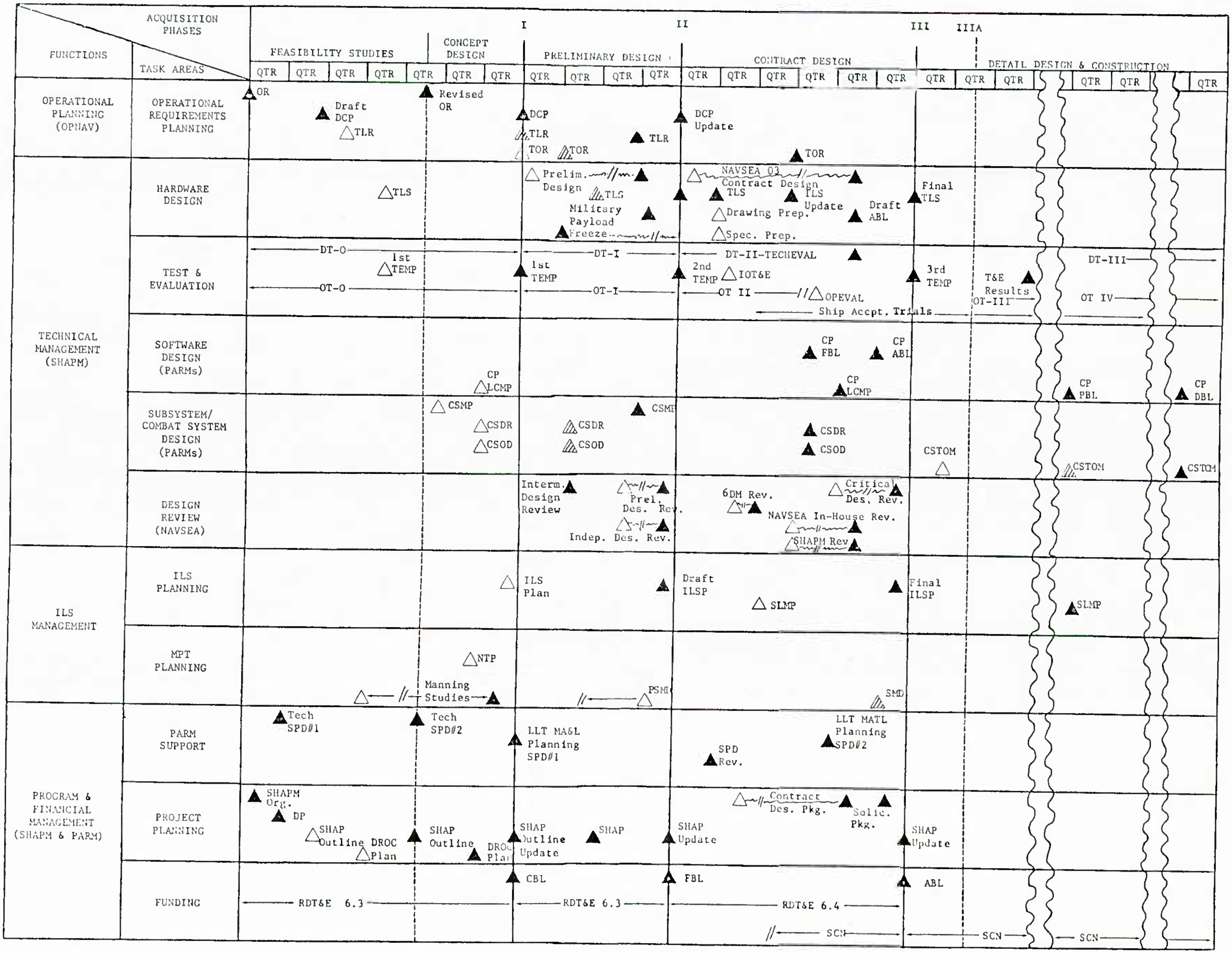


Exhibit V-6. EXAMPLE OF SUMMARY SCHEDULE

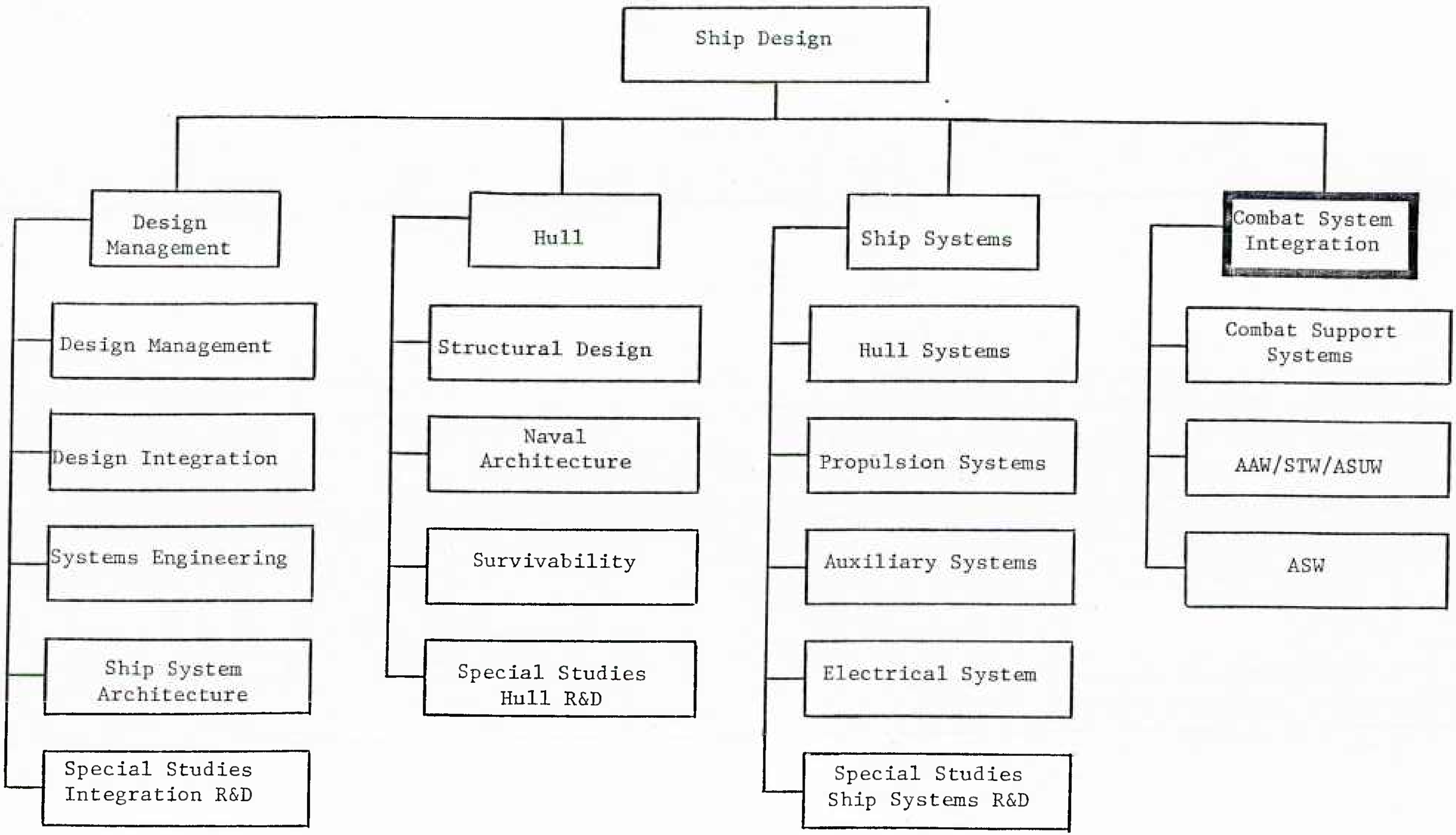


Exhibit V-7. SHIP DESIGN WORK BREAKDOWN STRUCTURE

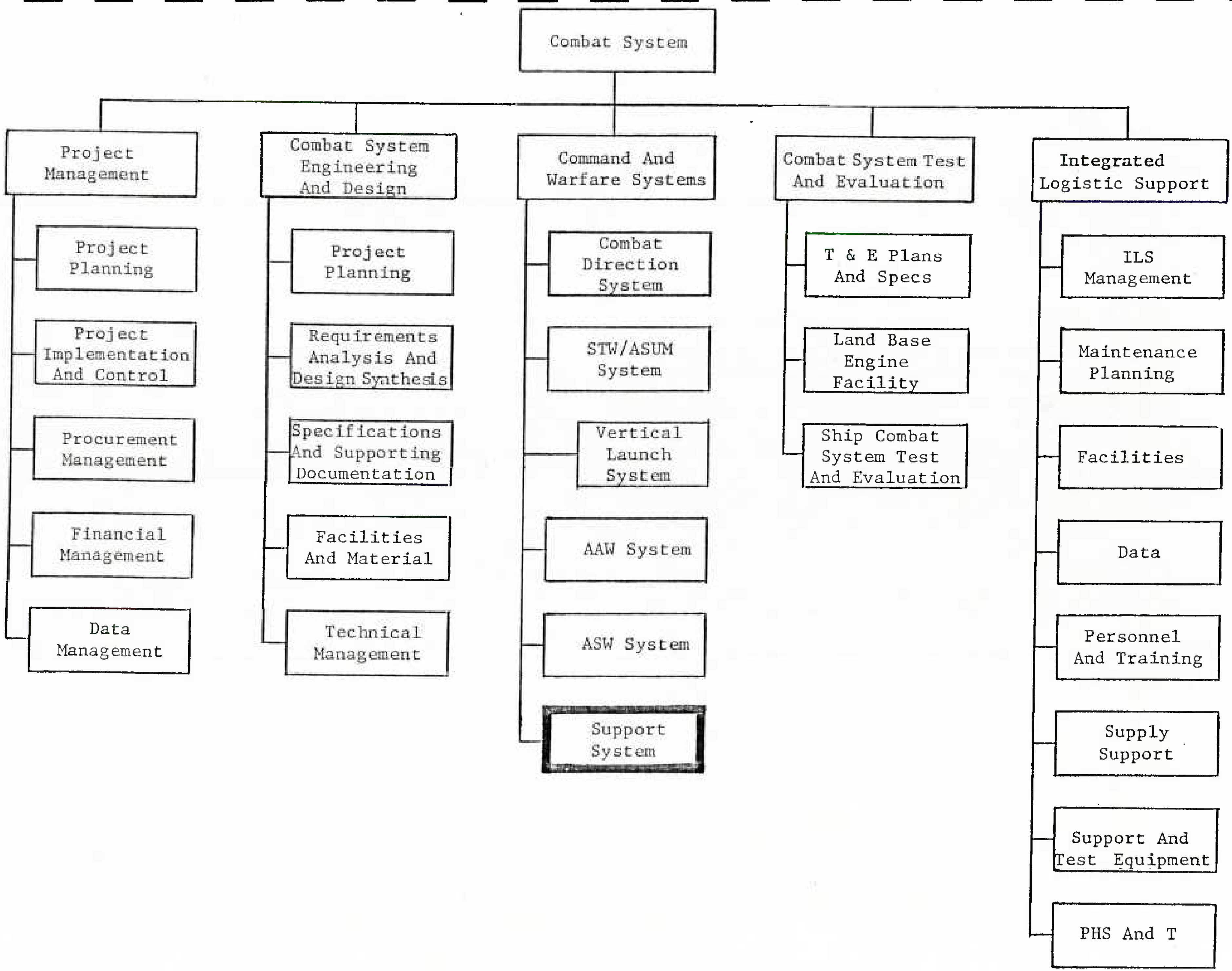


Exhibit V-8. COMBAT SYSTEM BREAKDOWN STRUCTURE

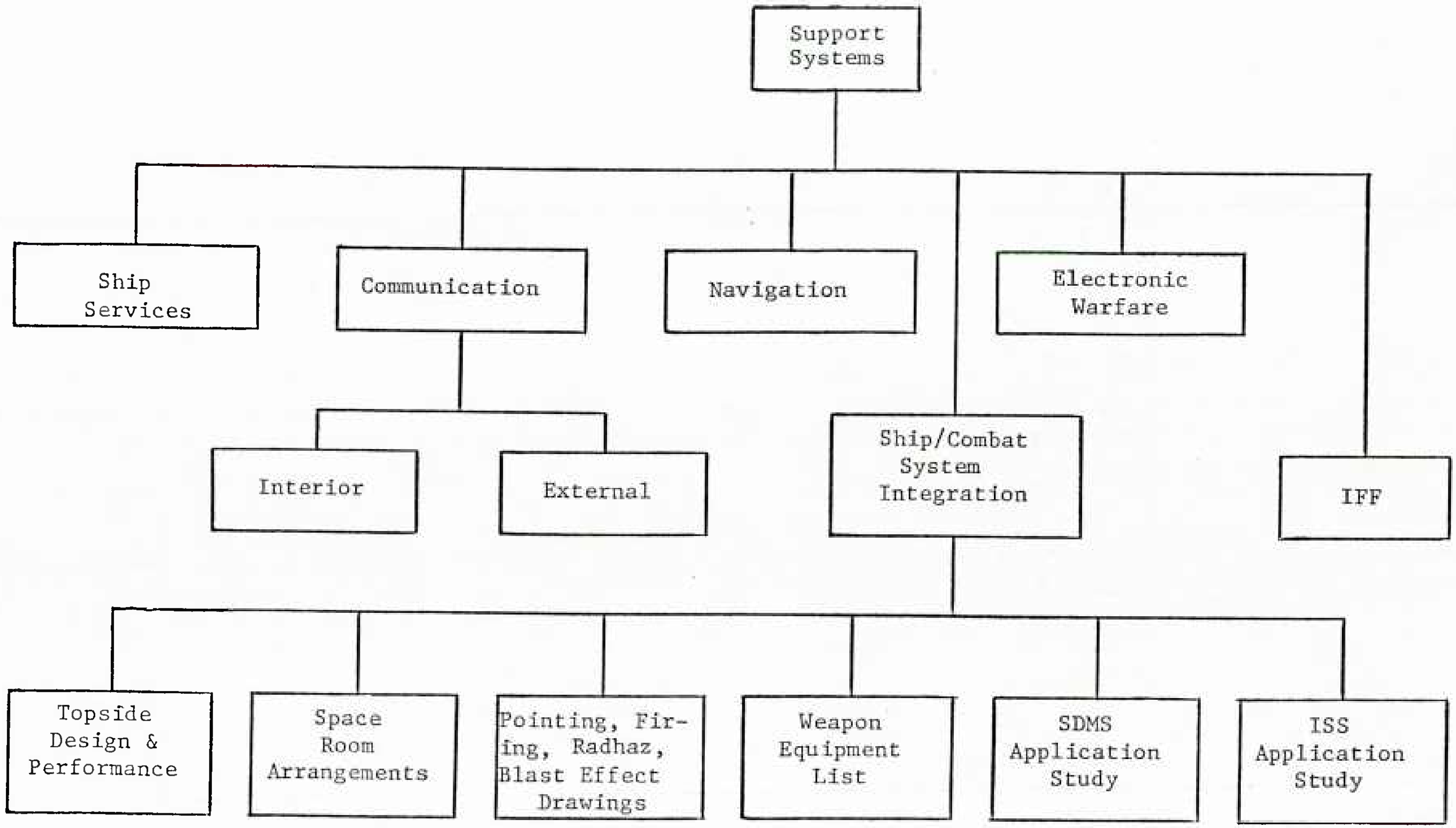


Exhibit V-9. SUPPORT SYSTEMS WORK BREAKDOWN STRUCTURE

3. Distribution of Project Design Responsibilities

The final consideration of particular interest to the PM/SHAPM is the assignment of the various design and acquisition responsibilities. In this discussion, as well as the previous discussions, responsibility for performing this analysis has been identified with the PM or SHAPM, in the case of ship acquisition projects. In actual practice this responsibility may be delegated to other members of the design or planning team such as the Ship Design Manager. All groups involved in the design effort will, at the very least, have to provide information in order to perform this analysis.

As can be seen from the preceeding discussions, project scheduling involves the coordination of a complex variety of groups and activities. Contributing to the complexity of this problem may be the need to obtain still more information from outside the specific systems command. For example, it has been noted that

> . . . ship design is not done solely within NAVSEA through the Contract Design. The Naval Electronics Command designs the interiors of the communications, electronic countermeasures, and intelligence spaces, as well as participating in the placement of those antennas. The Naval Supply Systems Command designs the interiors of all the galley and commissary spaces. The Bureau of Medicine and Surgery designs the interiors of the operating rooms. And the Naval Air Systems Command establishes many standards with respect to flight safety, determines requirements for maintenance and personnel, and lays out the hangar deck on a CV to determine the number of aircraft that a proposed design can hold. This adds to the complexity of the management problem.12/

12/ "The Changing Nature of the U.S. Navy Ship Design Process," Robert S. Johnson, Ship Design and Integration Directorate, Naval Sea Systems Command, 1980.

Design responsibilities may ultimately be assigned based on the determination of those which must be performed by certain groups, such as those discussed above, and those that are open to assignment by the PM/SHAPM. The ultimate designation of responsibility for performing, or seeing to the performance, of an activity may have substantial impact on the scheduling flexibility of these activities, since there may be a decided difference in response capability for work performed in-house and work performed by independent design agents. This has been a more recent problem in ship design:

> Today, only 28 percent of the (ship design) work is done "in-house" and the other 72 percent contracted out. These percentages do not truly reflect the seriousness of the situation. If one NAVSEC employee can technically manage and review the work of four contractor employees, this means that 18 percent of the total work is technical management. Thus, only 10 percent of the ship design work is actually "hands on" technical work in NAVSEC and most of that is ship integration. Hence, today the actual engineering of ship systems is being done by design agents and other private technical firms.13/

B. APPLICATION CONSIDERATIONS

Given this brief discussion of the planning needs and considerations of the PM/SHAPM, it is now possible to discuss more specific considerations related to actual application of the concurrency analysis methodology.

13/ Ibid.

As mentioned in the summary of the background research, concurrency has been most often thought of as overlapping of the full-scale development and production phases. In ship acquisitions concurrency has had a dual role:

> Concurrency is often used in two areas of the acquisition process to minimize the time required to acquire a class of ships. First, there may be concurrency in the development of the detail design and early construction efforts. Normally it is expected that subsystems or equipments will be tested and accepted for fleet use before they are designated for inclusion in a new class of ships. However, situations may arise in which major improvements are anticipated from equipment currently under development. In those cases, a decision must be made on whether to accept the lower performance available from proven equipment or to accept some risk by continuing development of new equipments that promise to meet the projected performance goals and completion schedule.
>
> The second aspect of concurrency is ordering the early follow ships before the first ship has been delivered and tested. The decision on the timing of the award for early follow ships and start of construction of these ships should refect a tradeoff between an acceptable level of risk that the lead ship will satisfy the stated requirements and the desire to deliver follow ships as early as possible so that they will have maximum useful life. It is because of the latter reason that decisions are made on most ship acquisition programs to not utilize the lead ship as a true prototype for the remaining ships of the class. Another reason for rejecting the prototype approach is that the ship system as a whole generally incorporates hardware which is off-the-shelf, state-of-the-art and therefore does not pose the kind of risk posed by a system comprised for the most part of advanced-technology hardware.14/

Decisions on the use and placement of concurrency are contingent upon several conditions:

14/ "Relationship Between Acquisition Strategy and the Contract Design Package," Advanced Marine Enterprises, Inc., Arlington, Virginia 22202, 22 February 1977.

- the magnitude of the constraint, i.e., the amount of time that the schedule must be reduced;
- the portion of the schedule affected by the constraint, i.e., the activities remaining to be accomplished or which can be rescheduled; and
- the opportunity to analyze the risks and impacts of making the decision.

As envisioned now, this analysis would be part of the overall effort to develop and update the acquisition program plan. This would mean that the concurrency analysis would be initiated in the concept development phase and identified in the outline of the acquisition plan. There are two reasons for advocating early-on concurrency analysis:

- the earlier the process is incorporated, the earlier the alternatives and risks can be identified and monitored; and
- the initial analysis may be complex, however, once the apparatus for performing the analysis has been developed, subsequent reviews will be easier to implement.

Early-on planning also allows the gathering of the necessary information and organization of the schedule to facilitate the concurrency analysis from the beginning. This is particularly critical due to the need to identify tasks or activities which are analytically compatible. The concurrency analysis rests on the ability of the analysts to determine how much of an activity is complete, or will be complete, at a given point in time. This is used in the calculation of the <u>degree</u> of dependence the activity has on other activities, combined with the degree of uncertainty related to the resource projections. The degree of uncertainty, in turn, is related to

how much of the activity has actually been completed at the time of the analysis, where the activity occurs in the sequence, how dependent the activity is on other activities, and how sensitive it is to exogenous factors. Exhibit V-10 illustrates the degree of technological uncertainty at progressive stages of the acquisition process. A similar pattern exists in the accomplishment of activities within these stages. It may, however, be more useful to the PM to measure activities not in terms of amount of work completed but rather by the completion of the amount of time allocated for the task. The only requirement is that whatever measure is used allows for a meaningful comparison of the tasks.

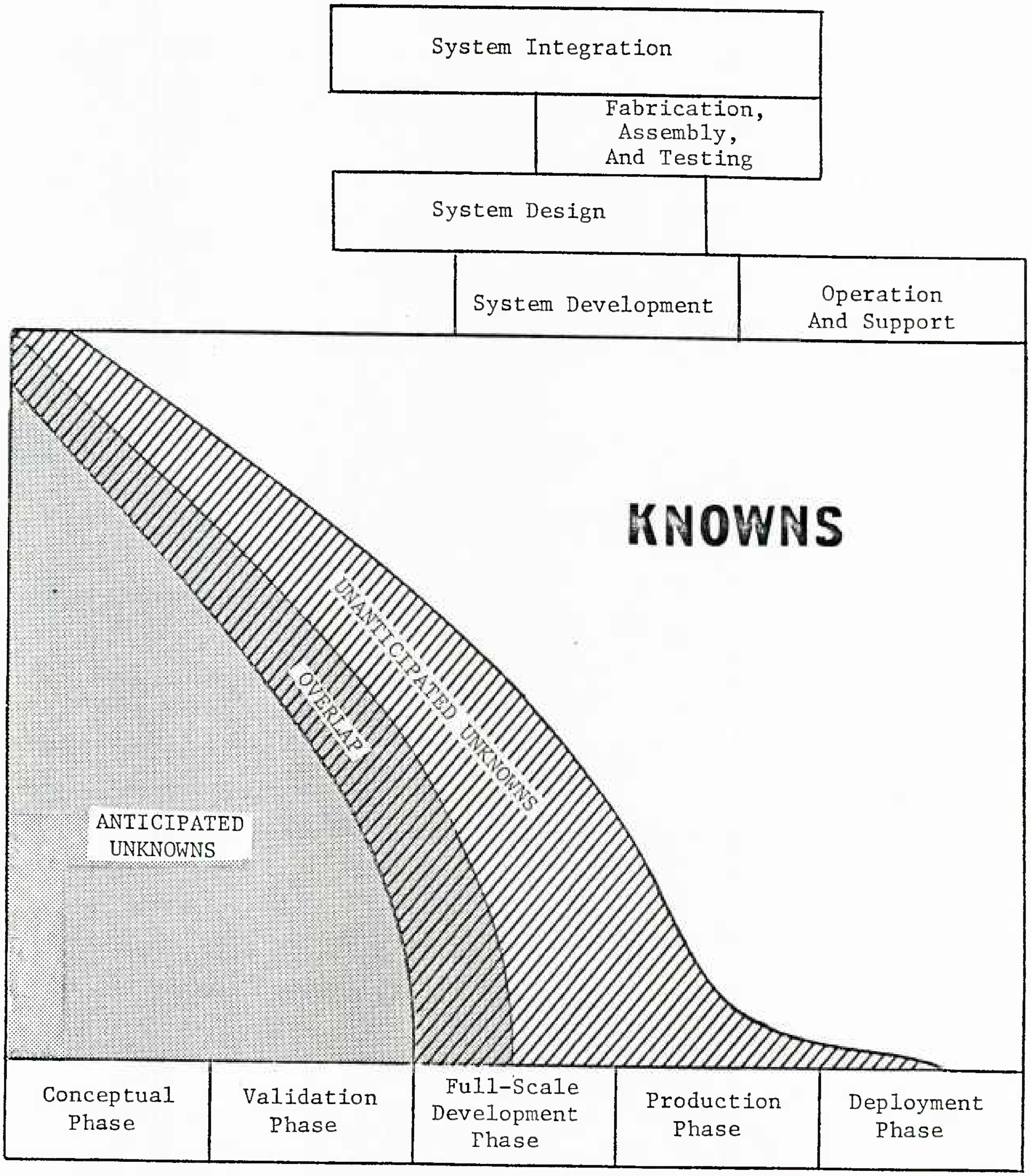
The ultimate goal of the methodology is to provide the decision maker with a tool for:

- identifying activities which can be concurrently scheduled, and
- evaluating the cost and schedule risks associated with them.

In order to do this the analysts must ask a series of qualitative questions which assist in determining the:

- degree of activity dependence,
- amount of acceptable concurrency to be permitted among difficult activities, and
- amount of acceptable cost and schedule risk considered tolerable for the planned scope of the concurrency.

Questions which would have to be answered would be, for example:



Source: K. E. Brandt, "Decision Risk Assessment and Analysis in the Weapons System Acquisition Process," USAF Aeronautical Systems Division, January 1974.

Exhibit V-10. THE DEGREE OF TECHNOLOGICAL UNCERTAINTY AT PROGRESSIVE STAGES (RISK)

- What information is needed to begin the activity?
- What are the sources of this information?
- Are they under the control of the PM/SHAPM?
- How much of the activity has been completed at this time?
- How much of the tasks which provide input information to this activity must be complete before this activity can be initiated?
- Is the source activity (the activity or task providing information), expected to meet its schedule? If not, how uncertain is this schedule?

The methodology is designed to use two different checklists. These checklists are to be used to:

- evaluate activities and events to determine concurrency options, and
- evaluate the cost and schedule risks associated with the different schedule alternatives.

In identifying the concurrency options, activities are initially categorized in terms of those that:

- can not be rescheduled, reorganized or reordered;
- might be possible to reschedule, reorganize or reorder, but for a variety of reasons are less desirable; and
- can be rescheduled, reorganized or reordered.

Initial emphasis would be placed on the third category. Assignment to any of the categories is based on current understanding of the conditions prevailing in the project. It is, therefore, possible that activities previously considered as unlikely concurrency options may, after further consideration, be re-categorized. As mentioned before, the identification

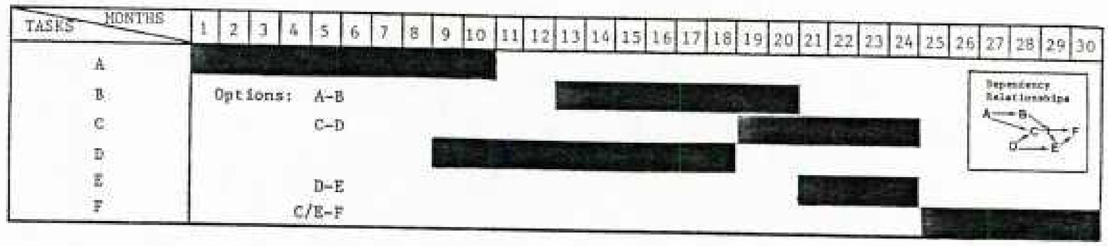
of potential concurrency options is of substantial importance since those options provide the basis for generating the alternative schedules.

The concurrency options are grouped in various combinations and with different sets of constraints in order to generate different schedules. An option comprises at least a pair of activities, composed of an independent or source activity, i.e., the activity which provides information to the dependent activity, and the dependent activity which succeeds the source activity and would begin before completion of the source activity. Options may actually comprise clusters of activity/event combinations, representing all of the sub-schedule activities related to a detailed schedule activity. The composition of an option is completely dependent upon the perceived requirements of the project. However, generally, dependent activities within an option should be:

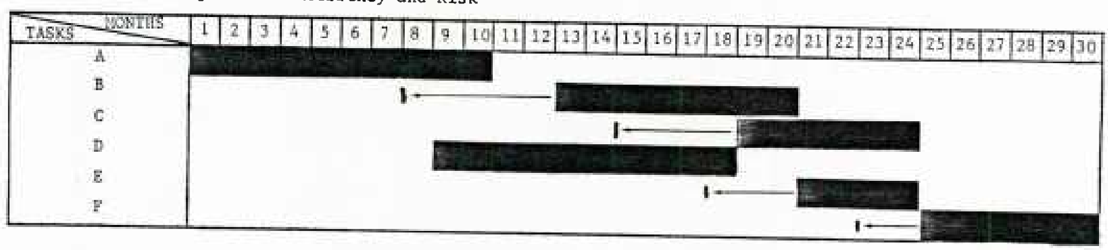
- under the control or direction of the PM, and
- influence the project cost or schedule duration.

Exhibit V-11 illustrates the basic relationship of concurrency options to alternative schedules. A sequence of activities, Tasks A through F, is shown. Based on analysis of the dependency relationships, the degree of uncertainty associated with them, and the role of each task in the total sequence, options are selected. The options, any or all of which may be used in generating the alternatives, are:

A. Baseline Sequence with Options



B. Acceptable Degree of Concurrency and Risk



Option	Degree of Concurrency	Acceptable Target Degree of Cost Risk*	Acceptable Target Degree of Schedule Risk*
A-B	• B + 5 Months/37.5%	10%	15%
C-D	• C + 4 Months/66.7%	30%	20%
D-E	• E + 3 Months/25.0%	5%	10%
C/E-F	• F + 2 Months/33.3%	20%	15%

* Degree of Risk = Probability of failure to meet estimated cost or schedule.

C. Alternative Schedule

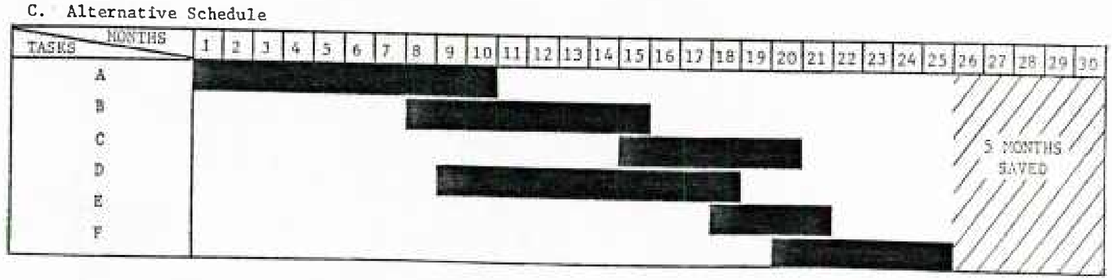


Exhibit V-11. RELATIONSHIP OF CONCURRENCY OPTIONS TO ALTERNATIVE SCHEDULES

- overlap of B with A, A-B option,
- overlap of C with D, C-D option,
- overlap of E with D, D-E option, and
- overlap of F with both C and E, C/E-F option.

Having determined the options, limiting values must be developed to use in generating the alternative schedules. The characteristics which are manipulated for each alternative are:

- the applicable concurrency options,
- the related resource estimates for each activity on the schedule (reflecting the additional constraints),
- the maximum acceptable degree of concurrency for each option, and
- the maximum acceptable degree of cost and schedule risk for each option.

Alternatives are structured taking into account the degree of uncertainty associated with the initial estimates. Part C of Exhibit V-11 shows the alternative generated base on the selection of options and tailoring of values for the characteristics.

After generating the various alternatives, it is necessary to evaluate the risks of each in terms of cost and schedule. The basic tools in this analysis are the cost risk evaluation checklists and the schedule risk evaluation checklists. They are designed to address the concerns the decision maker must keep in mind in order to weigh the alternatives. Exhibits V-12 and V-13 are examples of the kinds of considerations necessary for development of the checklists. Actual checklists would have to be tailored to the particular application at hand. The purpose of the risk evaluation is not only to estimate the potential risk

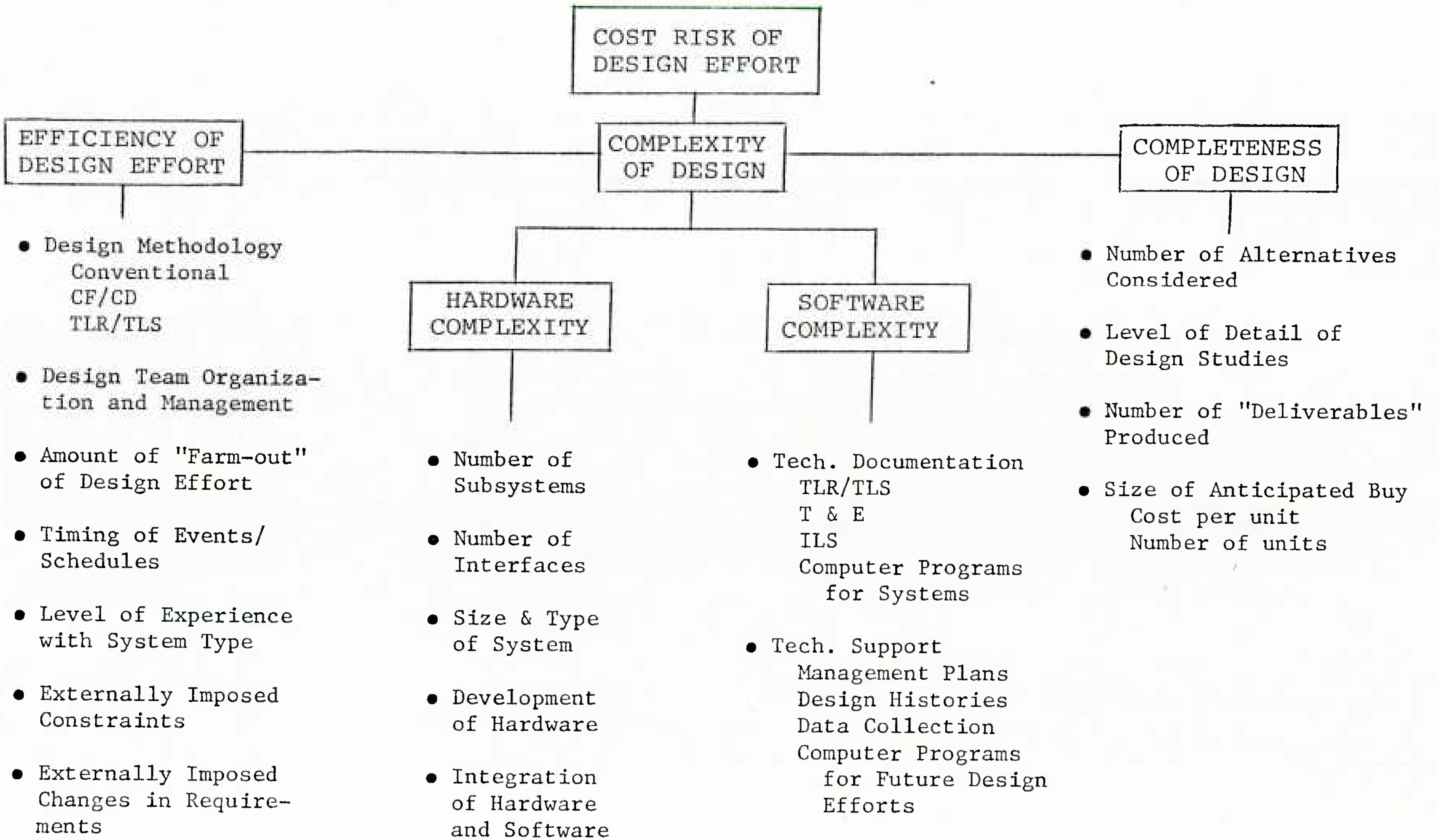


Exhibit V-12. COST RISK CONSIDERATIONS IN SYSTEM DESIGN

- Is the activity dependent on information or inputs from outside the performing organization?

- Is the manpower within the performing organization subject to fluctuation; i.e., is the performing organization responsible for performing similar activities for other programs and, therefore, the manpower must be competed for?

    - Does the ability to compete (or lack thereof) indicate relative value or importance and, therefore, can the program expect to have lower priority in other areas?

- How much of the input information is needed in order to begin the dependent activity?

- Is development of the input information from outside of the performing organization on time? Do they expect it to stay on time?

- What other parts of the schedule are dependent on this information? Information from this group?

- Has allowance for schedule slippage been incorporated in the time estimate?

- Have additional quality assurance measures been identified in order to reduce potential risks associated with concurrently scheduling the activity?

Exhibit V-13. SCHEDULE RISK CONSIDERATIONS

associated with each alternative, but also to rank the appropriateness of each alternative. It is possible to generate alternatives with mutually conflicting cost and schedule constraints or risks.

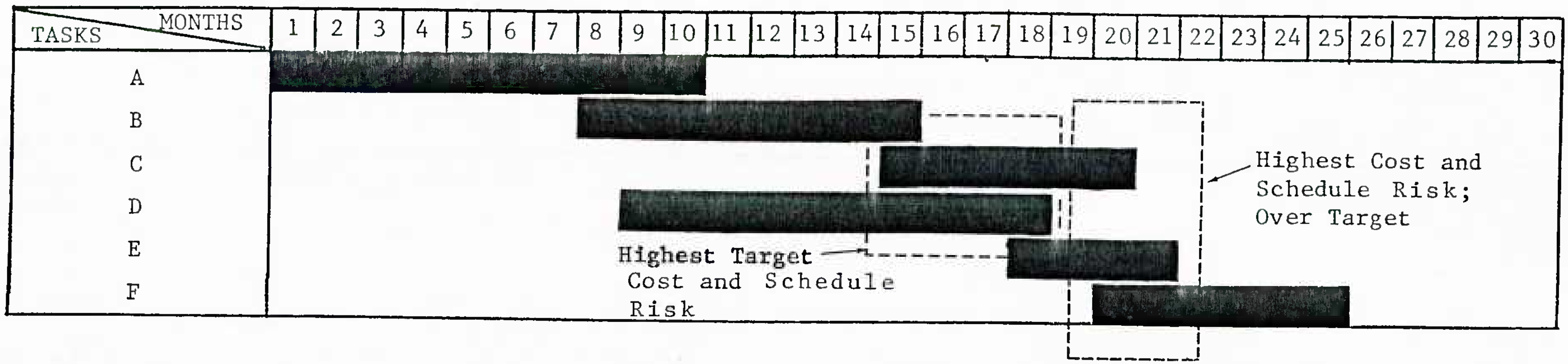
Exhibit V-14 illustrates the results of evaluating the alternatives generated in the example given in Exhibit IV-11. In addition to calculating the total amount of time saved, the specific cost and schedule tasks must be calculated for each option as well as the total for the alternative. As part of this analysis, it is also important to determine the "peak" risk, i.e., the options with the highest potential cost and schedule risk. This is particularly important if the potential risk is higher, or related to a different option than the original "target" degree of risk, as illustrated in this example.

The effectiveness of the application of the concurrency analysis methodology can be quantified once this analysis has been made.

Suppose that the portion of interest in the schedule for a particular project cannot be completed in less than T_O units of time, say months. Suppose further that the baseline schedule for that portion of the project has a duration of T_B months. If a concurrent schedule will complete the project in T_C months, then one measure of the effectiveness of the concurrency accomplished by the latter schedule is

$$D_C = \frac{T_B - T_C}{T_B - T_O}.$$

Alternative A.



Calculated Degree of Risk for Alternative*

Option	Cost Risk	Scheduled Risk	Position
A-B	20% (10%)	15% (15%)	Highest Target Cost & Schedule Risk
C-D	30% (30%)	20% (20%)	
D-E	5% (5%)	15% (10%)	Highest Potential Risk
C/E-F	35% (20%)	40% (15%)	Highest Potential Schedule Risk

* (%) = Acceptable Target of Degree of Risk for Option

Results of Evaluation of Alternative A

Effect of Concurrency: Gain 5 Months
Total Cost Risk:
Total Scheduled Risk:
Peak Cost Risk:
Peak Scheduled Risk:

Exhibit V-14. EVALUATION OF ALTERNATIVE SCHEDULE

Clearly, this is a relative measure since, for any given project, the potential effectiveness of applying concurrency will change as the completion time for the baseline schedule changes and the schedule progresses. Simply stated, this measure of the degree of concurrency gives the percent of time that can be saved in the baseline schedule that is actually saved by implementing the concurrent schedule.

Generally speaking, projects are not completed in the shortest possible time, e.g., in T_o years. That is because of budget limitations or the risks, technological and otherwise, that are introduced as one tries to shorten the acquisition time. Thus, the degree of concurrency sought, D_c, must be balanced against the risk of successful program completion within a specified budget and time, and producing a specified level of product performance.

In Exhibit V-15, D_c is plotted, for varying levels of T_o/T_B, against the term $(T_B-T_C)/T_B$. As used here, (T_B-T_C/T_B) is a measure of the percent of the time it takes to complete the baseline schedule that is saved by implementing the schedule with concurrency.

In selecting the alternative which will be used to revise the existing schedule, the decision maker must take into consideration the other scheduling alternatives which can be used in conjunction with concurrency.

Some of the alternatives he needs to consider are:

- funding of parallel activities, in order to increase the probability that one of the alternatives will successfully meet the goals of the program;

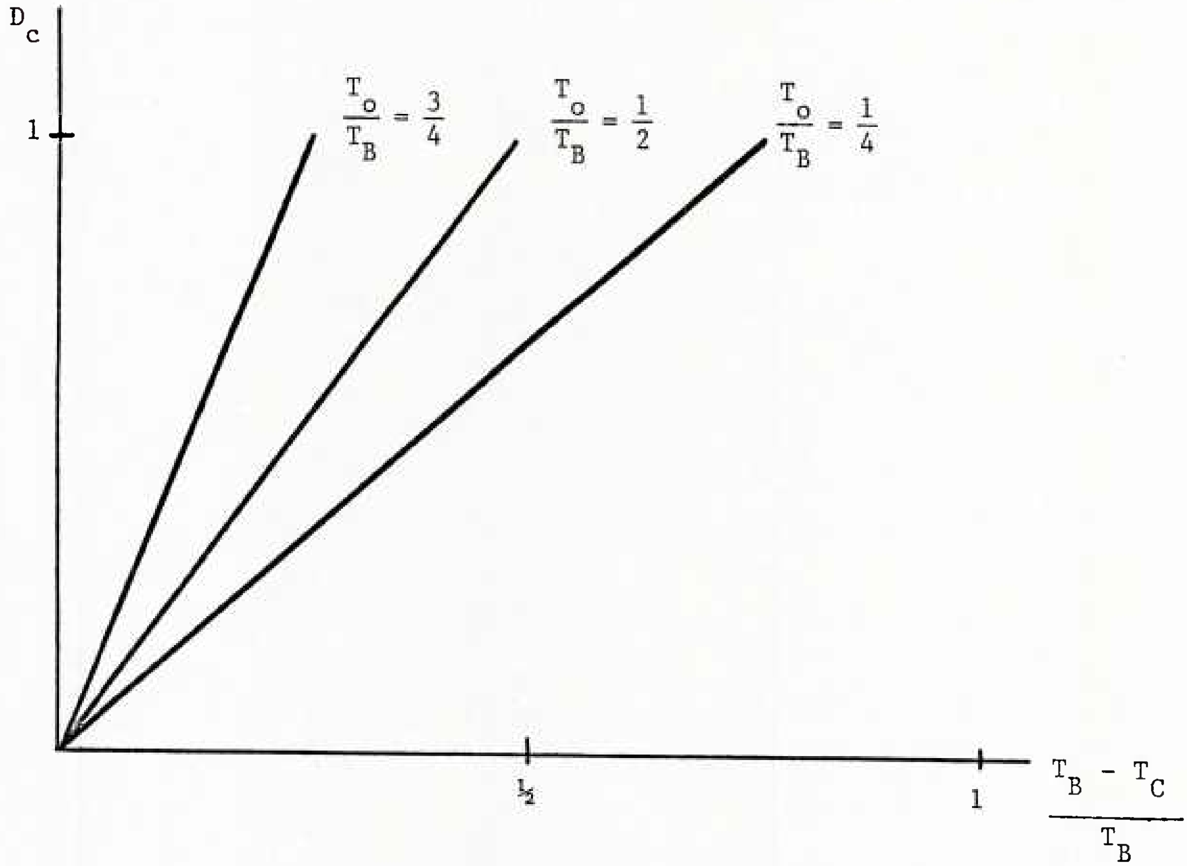


Exhibit V-15. THE DEGREE OF CONCURRENCY REALIZED AS A FUNCTION OF THE PERCENT OF THE BASELINE TIME SAVED

- funding repetition of activities, when a critical activity has not been previously successful;
- scheduling activity "slack time," to allow for the unforeseen extension of the duration of an activity; and
- lowering performance objectives of a high-risk activity and compensating by increasing the performance requirement for a lower risk activity.

The ultimate set of decisions made by the PM/SHAPM must reflect the particular needs of the project.

VI. CONCLUSIONS AND RECOMMENDATIONS

The following are MCR's conclusions and recommendations concerning our research on concurrency.

A. CONCLUSIONS

MCR's research on concurrency has led to the following conclusions:

- There has been no universally accepted definition of concurrency;
- Few studies have been conducted which specifically address the effects of concurrency on program acquisition;
- People have historically perceived concurrency to be a contributor to serious acquisition deficiencies; and
- Virtually no formal direction is provided to the Program Manager concerning techniques for developing or evaluating alternative program schedules.

Several major conclusions result from the research conducted on concurrency to date:

- To be effective, concurrency must be specifically planned for in the program.
- Due to the nature of the schedule planning process, however, there are limits to the horizon for concurrency planning.
- Techniques such as network analysis models and cost risk analysis models are useful in assessing the impacts of concurrency and are already available, but have not been coordinated into a consistent methodology useful to a Project Manager.
- In order to evaluate concurrency, the relationship between program events and activities must be defined and specific "checklists" developed so that techniques already available can be tailored to specific PM needs.

The Project Manager's dilemma is that he must (1) determine the magnitude of acceptable risk, and (2) apply a methodology

to quantify risk in order to effectively make cost/schedule/ risk trade-offs.

B. RECOMMENDATIONS

The lack of an acceptable definition of concurrency, one that is cast in operational terms and can be used as a basis for developing measures of effectiveness, has restricted the use of concurrency as a schedule modification technique. In order to define concurrency, it is first necessary to define the context in which the concept is considered, since the meaning of the unconscribed term is so general.

For the purposes of this analysis, concurrency must be considered as an acquisition strategy. It reflects a deliberately adopted approach for constructing and modifying a project schedule in order to perform trade-offs or prioritize goals. Two of the many trade-offs that can be analyzed in this context are:

- decreasing resource requirements (time, money, manpower) at the expense of increasing risk, and
- decreasing risk by increasing one or more of the resources attached to the schedule segment.

In defining concurrency, a distinction must be made between: those activities or events which, in the course of an acquisition, are scheduled to be performed at the same time because it is a standard procedure for ensuring an efficient smooth-running schedule; and those activities or events which are scheduled to be performed at the same time as a mechanism for responding to a constraint. Project schedule concurrency, in the context used

here, relates to the latter category, where the aim of the constraint is to shorten the acquisition time for the product or system at hand.

With these thoughts in mind, MCR has developed the following definition of concurrency.

> The simultaneous performance, in whole or part, of two or more normally sequentially related activities as a means of optimally utilizing resources or managing risk in response to an imposed constraint (schedule compression) or to forestall a scheduling crisis (schedule protection).

In order to develop an operational procedure for developing and evaluating project schedules that incorporate concurrency, the following steps must be performed:

- complete the development of the descriptive model to a fourth level of detail in order to accomplish a tailoring of the approach to a weapon system level of detail;
- develop weapon system specific checklists to help in the cost risk and schedule risk evaluation of project schedules;
- test the methodology using actual project data by applying the methodology in conjuction with an on-going acquisition progam;
- explore risk analysis techniques appropriate to the evaluation of schedules that incorporate concurrency; and
- draft a reference work on the implementation and evaluation of concurrency for use by Project Managers.

The goal of these steps is to provide Project Managers a useful guide and methodology for implementing the notion of concurrency in their projects. The aim of the approach is to develop an implementable methodology which will ultimately help shorten the acquisition time for major weapon systems.